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SYNTHESIS OF CENTRAL PLACE THEORY WITH NETWORK MODELS: DETERMINING FUNCTIONAL AREAS IN TÜRKİYE

AĞ MODELLERİ İLE MERKEZİ YERLER KURAMININ SENTEZİ: TÜRKİYE'DE İŞLEVSEL BÖLGELERİN BELİRLENMESİ

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Abstract

Achieving a well-balanced distribution of welfare across the country can only be accomplished through the use of comprehensive and complementary spatial plans that consider the spatial characteristics of the structure. The main determinants for these plans are functional areas and interregional relations. Central place and network theories have advantages relative to each other when applied to horizontal and hierarchical relations This study aims to put forward functional regions, regional centers, and hierarchical relations of provinces in Türkiye through an algorithm that synthesizes these advantages based on inter-provincial trade data. Although network models can reveal general characteristics of the inter-provincial network relations, importance of a specific province in the network, and horizontal relations and clusters; they are inefficient in determining regional centers and their hinterlands. To address this deficiency of network models is relieved through developing a rule-based hybrid algorithm with central places approach. The algorithm transforms the trade relations into a one-way structure, as in central places theory according to Gross Domestic Product (GDP) and geographic proximity of the provinces. This algorithm is convenient to apply and can be developed with additional constraints and different data for the spatial studies, such as rule-based functional regions and network models.

Keywords: Regional Development, Network Models, Central Place Theory, Functional Regions

Öz

Refahın ülke sathında dengeli dağılımı ancak mekansal özellikleri kapsayıcı ve tamamlayıcı bir şekilde ele alan mekansal planlarla sağlanabilir. Bu planlar için işlevsel bölgeler ve bölgeler arası ilişkiler temel belirleyicilerdir. Yatay ve kademeli ilişkilerin belirlenmesinde kullanılan merkezi yerler ve ağ kuramlarının birbirilerine göre üstünlükleri vardır. Bu çalışma, bu üstünlükleri sentezleyen bir algoritmayı iller arası ticaret verilerine uygulayarak Türkiye'nin işlevsel bölgelerinin, bölge merkezlerinin ve illerinin kademeli ilişkilerini ortaya koymayı amaçlamaktadır. Ağ modeli, iller arası ilişki ağının genel özelliklerini, illerin ağdaki önemini, yatay ilişkileri ve kümeleri ortaya koyabilmekte ancak bölgesel merkezleri ve bunların etki alanını belirleme konusunda yetersiz kalmaktadır. Bu makalede ağ modellerinin söz konusu eksikliği, merkezi yerler yaklaşımıyla kural tabanlı hibrit bir algoritma geliştirilerek giderilmiştir. Algoritma, illerin Gayrı Safi Yurtiçi Hasıla (GSYH) ve coğrafi yakınlıklarına göre ticari ilişkileri merkezi yerler kuramında olduğu gibi tek yönlü bir yapıya dönüştürmektedir. Bu algoritma, kural tabanlı işlevsel bölgeler ve ağ modelleri gibi mekansal çalışmalar için ilave kısıtlar ve farklı verilerle kullanılmaya ve geliştirilmeye elverişlidir.

Anahtar Kelimeler: Bölgesel Gelişme, Ağ Modelleri, Merkezi Yerler Kuramı, İşlevsel Bölgeler

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Introduction

Spatial dimension has always been an indispensable part of the studies on sustainable development, regional development disparities, and fair distribution of prosperity across a country. There is an increasing number of research efforts aimed at defining and classifying spatial structures and their relations. Regional scientists and policymakers are constantly seeking more effective ways to define functional areas, and inter- and intra-regional relations. In this dynamic and evolving field, new approaches are often developed by synthesizing the old theories with the new ones, particularly with the network models.

The fundamental studies on defining relations among settlements had begun with central place theory which exposes hierarchical relations thereof. On the other hand, recent advancements in transportation and accessibility have led to a greater emphasis on flows between the settlements. In parallel, new approaches based on the flows such as urban networks and network models are being widely applied in this field.

It has been observed that network models are more accurate than central place theory in some cases, and vice versa in other cases. However, these theories are not mutually exclusive, in fact, they are complementary to one another. Therefore, synthesizing them by combining their relative advantages may be a more effective approach.

Classification of regions based on functional relations is a growing research area that concerns planning of regions. Furthermore, commuting flows between the settlements have become a major focus for delimiting functional regions (Cattan, 2002:4). Similarly, other flows like human movements, migration, distribution of goods and services, communication among settlements have also become salient reference network data for delineating functional regions.

Türkiye has also seen similar progress in this field. Spatial planning began during the transition to planned economies in the 1960's. The aim was to use scarce resources efficiently and achieve a well-balanced distribution of welfare among the regions. To achieve this, both horizontal and hierarchical relations of settlements were analyzed, and regional policies were subsequently devised.

In this regard, Türkiye'de Yerleşme Merkezlerinin Kademelenmesi-1982 (Hierarchy of Settlements in Turkey-1982 "YERMEK") was one of the most fundamental studies. Based on the central place theory, YERMEK revealed spatial socio-economic relations and interactions, regional centers, and sub-regions based on data of trade, education, health, transportation and communication, and seasonal migrations (State Planning Organization, 1982:17).

There are also studies facilitating decision-makers in developing integrated and balanced development policies at national level, and in devising policy interventions to alleviate intra-/interregional development disparities. In this scope, studies for determining socio-economic development level of provinces, districts and regions (Acar et al., 2019), and delimitation of 26 NUTS-II regions and growth poles in Türkiye (Bilen Kazancık, 2013), and recent study of Beyhan (2019) specifying functional regions among districts by developing and using his algorithm FRGIS can be seen as primary sources for regional policies.

On the other hand, Öztürk (2009) delimitates functional regions via Consistent Intramax Analysis by using interregional migration flow data. Another study, determines regions based on migration flow via a hybrid algorithm developed by Bilen Kazancık and Bilen (2020).

Türkiye'de Kentsel ve Kırsal Yerleşim Sistemleri Araştırması Projesi (Urban and Rural Settlement Systems Research Project in Türkiye "YER-SIS"), was conducted by the Ministry of Industry and Technology (2020) in which a similar algorithm was applied to determine settlement systems. The aim of YER-SIS is to define the current settlement system and relations between settlements in Türkiye within the framework of new dynamics. YER-SIS was completed using a hybrid approach that integrates the theory of central places with network analysis methods, based on a large data set with various themes, as well as a comprehensive survey study conducted throughout Türkiye.

Within the scope of YER-SIS study, areas of influence for urban service centers and regions were established. With the impact areas, urban settlements are evaluated as a whole in relation to the other settlements they interact with and the regions are delimited.

A similar method was used in our study, but in the YER-SIS study, the data was made one-way using the generalized degree distribution, However, in our study, the data was made one-way over the Gross National Product value. Additionally, a district-based study was carried out in YER-SIS, an area of influence was created over the districts. Our study based on trade data of provinces and the impact areas of them are obtained.

This study combines network models with central place theory by using trade flow data to determine the functional areas and hierarchical relations. In general, network models are reasonably convenient for determining global centers, horizontal relations, and the roles of settlements within networks, but they are not well-suited for determining hinterlands and functional areas in a hierarchical order. Regions can be delimited without designating some locales as centers of a predefined hierarchy. Basic spatial units (BSUs) are assigned to one another without identifying any central BSUs according to the magnitude of interaction between them. (Beyhan, 2019). Although the algorithm developed in this study has similarities with the algorithm of Nystuen and Dacey (1961), it is enhanced by new constraints and rules to obtain aforementioned hierarchical regions. Additionally, it provides an appropriate basis for the evaluation of spatial proximity and relations together.

This study aims to contribute to efforts in delimiting the functional regions through the use of a hybrid algorithm. By synthesizing central place theory with network models, the algorithm is well-suited for identifying hierarchical levels and units within each level. It also provides a systematic approach for analyzing both horizontal and hierarchical relations. Furthermore, it is applicable to similar studies and can be further developed with the addition of new constraints and rules.

The first section of this paper begins with literature review of recent developments in central places and network theories. The subsequent section explains the "central place theory" and "network theory" algorithms used in the analysis. The following part presents the proposed hybrid algorithm that utilizes the assumptions of central place theory and network theory. The results of the analysis are deliberated via tables, maps and network visualizations produced by R packages. Finally, all the findings and inferences are summarized in the conclusion section, and proposals for the use and further development of algorithm for research in this field are introduced.

1. Literature Review

Regional science, particularly geography, is interested in spatial structures, relations between settlements, and delimitation of regions. Due to its interdisciplinary nature, these fields must contend with some complex and often blurred concepts. As a result, various theoretical and methodological approaches have been put forward to analyze the regional structures and functional areas.

In this context, early theoretical and applied approaches towards spatial structuring of settlement systems included studies on agricultural production by Von Thünen, site selection for industry and distribution of sources by Weber, and trade and service work by Reilly and Christaller. Thereafter, these economy-based studies have been expanded to include to social and cultural issues.

In the meantime, many studies have been conducted to identify settlement systems. One of them was Rank-Size Rule which was developed by Zipf in 1949 to identify the size and determine the hierarchical rank of settlements (Batty, 2006). Another study was carried out by Davies in 1967 in which he evaluated a centrality index based on the functional attributes of centers in South Wales. There were also various studies on settlement structures prior to the Central Place Theory, but Christaller was the first to explain the urban location of settlements according to their "centrality" (Parr, 2017).

The Central Place Theory, developed by Christaller and Lösch, aims to determine the relative size and geographical distance of settlements as a function of service providers. Considered a milestone in human geography, the theory differentiates centers by their attributes and service types, and lays out a hierarchical structure (Pumain, 2006).

With a new perspective on spatial structuring, Haggett and Chorley (1969) proposed factors of spatial structures and divided them into 5 groups: movements, networks, focus, surface and diffusion, and later added the hierarchy to them.

Subsequently, Morrill (1974) in his book "The Spatial Organization of Society" conducted further research on evaluating complex spatial structures based on preferences for site selection, emerging hierarchies and spatial interaction. (Morrill, 1974, as cited in Klapka et al., 2010).

Graham and Marwin (1996) have highlighted that multi-level functional hierarchies of central places are being replaced with the interlinked urban networks due to the advancements in transportation and communication technologies. In the 1990s, a new spatial model known as "network theory" (Camagni, 1993; Batten,1995; Capello, 2000) emerged, which is built on the premise that hierarchies emerge between the functions of urban areas, rather than the urban areas themselves, and that the relationships between urban areas are formed not only on vertical but also on horizontal axes (Çöteli, 2012: 33 as cited in Meijer, 2007).

Urban networks are defined based on the relations or flow systems which take the form of horizontal (not hierarchical) structures. This provides externalities of economies such as specialization, complementarity, spatial work division, collaboration, innovation between specialized centers (Camagni,1993). The non-hierarchical relations were also emphasized by Batten (1995), and the differences between central places and network systems were summarized as in Table 1.

Table 1: Central Place versus Network Systems (Source: Batten, 1995, p.320)

Centrality	Nodality
Size dependency	Size neutrality
Tendency towards primacy and subservience	Tendency towards flexibility and complementarity
Homogenous goods and services	Heterogeneous goods and services
Vertical accessibility	Horizontal accessibility
Mainly one-way flows	Two-way flows
Transport cost	Information costs
Perfect competition over space	Imperfect competition with price discrimination

On the other hand, central place theory has been evolving with new approaches and models. Moreover, many researchers argue that central place model should be integrated with other models, instead of replacing with it, rather than being replaced by them, since each model addresses different perspectives and circumstances (Çöteli and Yenen, 2012).

For this reason, there is no single approach to the central place theory but rather many variants depending on the time, field of study, and research objectives. For instance, Hall (1998) posits that hamlets and towns which are in the lowest hierarchy of Christaller, are removed from the urban hierarchy, and global and sub-global levels are added to the top of the urban hierarchy instead. Additionally, Dale and Sjoholt (2007) describe the general socio-economic changes in the central place system that have occurred in the central part of Norway (Trodelag) for a period of 40 years.

Furthermore, Burger et al. (2014) focused on the relations between retail trade and spatial structure in the Netherlands, and argued that many socio-economic processes, such as shopping, still occur locally. In another study, Boussauw et al. (2014) examined home-school travel time in the northeast of Belgium, and evaluated the effects of spatial distribution of schools and to what extent the density of primary school network supports daily urban system. Additionally, Dessemontet et al. (2010) defined a spatial system based on daily commuting time between 1970 and 2000 in Switzerland, and proposed polycentric models with workplaces surrounded by residential areas, instead of monocentric cities in the late 20th century.

The delimitation of regions is a core research area for settlement systems. In this area, the functional regions approach is widely accepted and employed in many studies. It is influenced by the central place theory by focusing on the linkages between the places, rather than similarities, and emphasizes the effects of urban centers on their peripheries. Additionally, it lays out the cities in region-wide networks based on node regions theories and central place hierarchies.

On the other hand, Nystuen and Dacey's study (1961) is recognized as the first study of functional regions which orders and groups settlements based on size and direction of communication flows. Based on Nystuen and Dacey method, Grubesic and others (2008) laid out nodal regions by flow variables such as the number of airway passengers and flights. Furthermore, Haggett and Chorley (1969) introduced a systematic application of graph theory in spatial structural analysis.

Functional economic regions resemble hierarchical spatial structures of central places. In general, a region is composed of a larger city and its hinterlands, which include smaller nodes. However, not all functional regions are nodal regions. Some functional regions may have two or more centers, and some others may not have a strong center dominating all the other settlements in the system. A functional region can be identified as an integrated economic system, which is delineated by interactions that take place in the networks of goods and services distribution, commuting routes, and communication (Karlsson and Olsson, 2015).

The first study on the classification of functional regions for planning purposes was conducted by Brown and Holmes in 1971. Subsequently, Coombes et al. developed CURDS' (Center of Urban and Regional Development Studies) algorithm in 1986, which utilizes commuting data. Pálóczi et al. (2016) applied this algorithm to determine functional regions in Hungary. Another algorithm (TTWA, Travel To Work Area) was developed by Coombes and Bond in 2008 which utilizes commuting flow data of commuting between settlements. This algorithm was implemented by Franconi et al. (2016) as R package named "Labor Market Areas", (Ichim et al., 2020).

In the context of determining functional regions, local and regional labor systems are often considered as the primary reference points (OECD, 2002). Furthermore, many experts maintain that the most essential characteristic of a functional region is an integrated labor market which encompasses factors such as commuting between regions and the intra-regional alignment of job vacancies and labor in contrast to interregional counterparts. There is a burgeoning trend that commuting flow of labor is mostly preferred amongst population flows for the classification of functional regions since commuting with daily periods are the most frequent and stable motion of population.

In addition to the labor market, various flows reflecting socio-economic relations are also considered in the determination of functional regions. A range of spatial interactions such as mutual complementarity and dependency, population flows (such as commuting to school, migration, shopping, and entertainment), traffic and commodity flows (including passenger flows via highway, maritime and airways), financial flows, information flows (such as communication and newspaper roaming), and flows of gas, water and electricity (such as service connections) have been employed for identifying heterogenous functional regions (Drobne, 2017).

OECD has published research on identifying functional regions and functional urban regions in certain OECD countries (OECD, 2020). In most of these countries, functional regions are modeled by using the concept of local employment areas. These micro regions are identified as "local labor market areas/micro regions" in Austria, Czech Republic, Finland, Germany, Portugal, Sweden, Switzerland; "local/regional employment systems" in Italy, Hungary and Poland; "commuting area" in Denmark and UK; "economic regions" in Norway; "functional urban and employment areas" in France; and traditionally "metropolitan regions for commuting" in USA and Canada (OECD, 2020).

There have also been various studies conducted for determining horizontal relations among the settlements. In this respect, Serrano and Boguná (2003) studied world trade as a network with 179 nodes and 7510 directed links. In a similar study by Hanousek (2014), the topological traits of international trade networks were scrutinized by network analysis by measuring linkages, variation and clustering, and analyzing the important statistical distributions of networks.

Similarly, Çubukçu and Özbay (2016) set and analyzed a relational network representing exports among 20 countries. In another study, Abbate et al. (2018) obtained the international trade network clusters and revealed how the topology of international trade changed over the geographic area with time. In addition, Khrazzi et al. (2017) presented the change in structural traits of global trade networks during 1996-2012 and examined its relation to economic resilience in terms of 2009 global economic crisis.

On the other hand, Chaney (2014) analyzed the export dynamics of firms through network analysis and found that firms tend to export to markets with which they have established communication and use the existing contacts to find new trading partners. Within the framework of the complex network approach, Soyyiğit (2015) analyzed the international trade networks for consumption, intermediary, and investment goods in the manufacturing industry for the years 1998, 2003, 2008 and 2013.

With regard to clustering, Demirgil et al. (2000) examined the tourism sector in Alanya to identify clusters and structures in tourism networks. The study analyzed clustering, cooperation and network relations by clustering analysis and mapping.

Clustering algorithms are frequently applied to unweighted and undirected networks. However, the Leiden algorithm has been developed to cluster directed and weighted networks (Traag et al., 2019). As the algorithms do not rely on the centrality and hinterland relationships, it is quite possible to group distant non-neighboring settlements into the same cluster. Additionally, models that are based solely on hierarchical relations may not achieve regional integrity.

In conclusion, neither network-based nor hierarchical approaches alone are sufficient to fully describe functional areas; thus, studies tend to focus on hybrid approaches to combine their superior features. There are numerous methods for defining of functional regions, and various classification schemes for these methods exist. Coombes (2000) categorizes these methods into three groups (Coombes, 2000, as cited in Beyhan, 2019):

- clustering methods;
- methods using hierarchical algorithms;
- rule-based method

Given that this study requires specific rules to reveal hierarchical structure of settlements, a "rule-based algorithm" was selected as the classification method. Rule-based algorithms establish rules based on pre-defined criteria, and are also referred to as multi-stage methods. Within this study, an algorithm that utilizes suitable parameters and is capable of revealing functional areas with meaningful agglomerations was developed and applied. The use of this algorithm is expected to reveal hierarchical relations while maintaining the neighboring settlements in a group horizontally, to identify central nodes and their hinterlands.

2. Method

2.1. Central Place Theory

Central place theory concerns itself with explaining the size, number, functional characteristics and spatial configuration of settlements within a regional system. The foundations of this theory, which dates back to the 18th and 19th centuries, were established by the German geographer Walter Christaller and refined by the German economist August Lösch (Malczewski, 2009).

According to this theory, a central place serves as the focal point of a settlement system or transportation network, providing goods and services to the surrounding area. The central places system, on the other hand, constitutes a network in which centers with different functions and sizes are interconnected in a hierarchical spatial pattern. In this context, the theory of central places is based on two fundamental concepts: threshold and range.

Threshold: The minimum level of population or demand required for providing a good or service. Adequate demand must be present to cover operational costs in the delivery of goods or services. This demand, referred to as the threshold, is deemed necessary for the preservation of the central function.

Range (spread area): The maximum distance that a consumer is willing to travel to obtain a good or service, or the area where the good or service can be provided. The range varies depending on the products: low-cost, frequently used and low-level goods and services have a more limited range, while high-cost and infrequently used high-level goods and services have a wider range.

Central place theory focuses on the one-way vertical relationships between places at different levels in a hierarchical structure. The one-way relationship indicates that lower-level central places are dependent on higher-level central places. In this theory, horizontal relationships between the settlements are not emphasized because they are similar in size and offer the same goods and services.

2.2. Network Theory

Network theory is an approach that visually and mathematically models the systematic structures hidden within complex systems by analyzing the relationships between the units. Barabási (2016) emphasizes that by understanding and visualizing networks, they can be managed and their effectiveness can be enhanced. Through network theory, groups of units can be identified, significant connections and nodes can be determined, roles and locations can be discovered, and hidden connections can be revealed (Bender-de Moll, 2008).

While traditional research methods focus on the relationships between dependent and independent variables, social network analysis focuses on relationships and patterns between units. There is no distinction between dependent and independent variables, and it is based on the philosophy that everything can explain everything (Sert et al., 2014). In networks, units are referred to as "nodes" and the relationships between units are referred to as "links". Depending on the nature of the relationship, connections can be "directional" or "non-directional". Networks can be visualized using the graph theory of mathematics. For this purpose, various drawing algorithms (such as Fruchterman-Reingold, Harel-Koren Fast Multiscale, and Sugiyama) have been developed.

As the number of nodes and connections in the graphs for network analysis increases, the understandability of network graphs decreases. In this case, network and node statistics are employed. Network statistics such as density, degree of connectivity, degree distribution, centrality and clustering can be used to see the systematic structure of the network, to compare different networks, or to understand changes that occur in the network over time. The definitions for some network terms used in the study are summarized below:

Centrality: Centrality is a concept that is applied to nodes, and it is used to express the centrality of a node in a network (Kervankıran et al. 2018; Marin and Welman, 2011). To reveal the importance of the unit in the network, it can be measured according to the size of its degrees, its average proximity to all other units, the frequency of being on the shortest path between units and the frequency of connection with important units. Each measure assesses and compares the different aspects of the nodes in the network analysis. Therefore, various centrality measures have been defined in the literature. Centrality measure assigns numerical values to each unit in the network, thereby allowing for comparison and ranking of the units based on these values.

Degree Centrality: It is defined as the number of relationships of one component with others. Degree can also be described in weighted and directed relationships. In directed networks, the degree of settlement is defined as:

$$\text{In Degree}: \; d_v^{in} = \textstyle\sum_j w_{j \to v} \quad (1)$$

$$\text{Out Degree}: \; d_v^{out} = \textstyle\sum_j w_{v \to j} \quad (2)$$

Closeness Centrality: Closeness was defined by Bavelas (1950) and refers to how close a unit is to the others in the network, based on geodesic distances. In the graph theory, the distance between two vertices v and w in a graph G is the number of edges of the shortest path that connects the vertices v and w, called Geodesic Distance and denoted by dg (v,w) (González and Cascone, 2014).

Closeness centrality of a unit is calculated as the average of the shortest path lengths from the unit to all others, or the reciprocal of the total shortest path lengths from the unit to all others, as given below:

$$\text{Closeness}: \; C_v = \frac{1}{\sum_{i \neq v} d_{(v,i)}} \quad (3)$$

Betweenness Centrality: Freeman (1977) provided the first formal definition of betweenness centrality. It is a measure of how many times a unit (v) is found in the shortest paths between all the units (pst). It indicates how effective a node's position is in controlling the flow of information between all node pairs.

$$\text{Betweenness}: \; C_v = \frac{\sum_{s \neq v \neq t} p_{st}(v)}{\sum_{s \neq v \neq t} p_{st}} \quad (4)$$

Centrality measures can be further derived for the purpose of the analysis and can be used to compare nodes in a network. It is also possible to create measures that represent the network as a whole and use them to compare a group of networks with each other. However, this is beyond the scope of this study, so only the measures defined above will

2.3. An Algorithm Proposal for Identifying Functional Regions

The primary objective of this study is to create hierarchical regions from interrelated local units. To achieve this, a hybrid algorithm is proposed, which utilizes the assumptions of central place theory and network theory.

In central place theory, it is stated that sub-settlement units go to larger places or places with more functions to access services that are not available locally or to access specialized services. According to threshold and range concepts in the algorithm, the destination place is defined as the center and the origin place is considered a unit within the hinterland of the center. Therefore, for a province to hold another province in its hinterland, it must be larger and have more functions than the other.

In this regard, the GDP of the provinces is defined as the "Centrality Index", and divided into 5 groups according to the natural breaks. Jenk's algorithm, which minimizes within-group and inter-group variance, was used in the single variable distribution classification. This results in the formation of homogeneous groups. The algorithm is commonly used in the literature. The provinces in the first 4 groups are considered to have potential to be regional centers and economically developed centers. In addition, a new centrality matrix is created by making pairwise comparisons of the provinces according to the "Centrality Index", with the assumption that the larger province dominates the smaller one. With the help of these matrices, a one-way trade relationship matrix was obtained.

In order to prevent the provinces that are geographically disconnected but have strong relations from being located in the same region, the algorithm enforces a neighborhood constraint and creates a neighborhood matrix.

If only the number or weights of links representing goods or services sold under the neighborhood constraint are considered, it is observed that the western provinces have larger centrality index values compared to the eastern provinces. Therefore, provinces that have potential to be regional centers based on the centrality index are not considered as centers if they are in the hinterland of a larger center i.e., they are closer than 200 km to the larger center. This distance constraint is established by considering the metropolitan areas and their hinterlands in Türkiye.

Moreover, provinces that fall into the last group of the centrality index are identified as prospective regional centers, if they are connected to 2 or more provinces. Additionally, if a prospective province is linked to another province in the last group, the linked province is upgraded and designated as the prospective regional center. In this framework, the main steps of the algorithm are outlined as follows:

1. **Step:** Refer GDP data as centrality index, mi of the province-i. Divide this index list in to k-groups by Jenks natural breaks as GDP is not evenly distributed among the provinces. Except for the bottom group, assign the provinces in upper groups (first k-1 group) as prospective regional centers P.
2. **Step:** Compose a matrix $m_{ij} \epsilon M$ with n*n dimensions as to representing the superiority between the units based on the centrality index (m_i). Assign $m_{ij} = 1$ if $m_i \leq m_j$, or$m_{ij} = 0$ otherwise. It indicates the direction of linkage.
3. **Step:** Construct a "T" trade matrix with n*n dimensions referring trade flows between the provinces.

   $t_{ij} \in T$ refers to value of goods and services bought by province i from j.
4. **Step:** Build a "D" matrix with n*n dimension indicating neighborhoods between provinces.

   $d_{ij} \in D$ refers to neighborhood between province i and j where $d_{ij} = 1$ if they are neighbour, or $d_{ij} = 0$ otherwise.
5. **Step:** Derive a$n_{ij} \in N$ superioritymatrix with n*n dimensions. Calculate n_{ij} by taking index values, neighborhood and priority index values of provinces into account and find the most dominant province j on province i. For each province i$\in [1, n]$ $and\ Z$;

   $$n_{ij} = 1\ if\ (t_{ij}\ .d_{ij}\,.m_{ij})\ is\ maksimum\ \ for\ j \in [1, n]\ and\ N;\ or\ n_{ij} = 0\ \text{ otherwise.}$$

   This means province-i is linked to or in the hinterland of j, if province-j is a neighbor and superior to province-i in GDP, and delivering the highest amounts of goods and services among other provinces.
6. **Step:** Generate first relations on superiority matrix N. If provinces are initially in lowest group and have 2 or more provinces in their hinterland, upgrade them to an upper level, and add them into the group of prospective regional centers P.

   In addition, if such a province is linked to another in the lowest group, upgrade the other province to upper level and add it to the group of potentially regional centers P.
7. **Step:** Derive a connectivity matrix "B" with n*n dimensions indicating the connectivity of the provinces in the group of potentially regional centers P.

   In this group (P), $b_{ij} = 0$ if the distance between provinces i and j is longer than 200 km. orb_{ij} =l lotherwise.

   For the provinces which are not in the group P, then $b_{ij} = 1$.
8. **Step:** Set up the conclusion matrix $s_{ij} \in S$ by employing trade, superiority and connectivity values, and finding the most dominant neighbor province-j for the province- i.

   $S_{ij} = 1\ \ if\ (t_{ij}.d_{ij}.m_{ij}.b_{ij})$ is $maksimum\ for\ j \in [1, n]\ and\ N, or\ \ S_{ij} = 0$ othjerwise.
9. **Step:** Construct the regions and stop.

The primary distinction between the proposed algorithm, and that of Bilen Kazancik and Bilen (2021) is that in the proposed algorithm, if the distance between neighbor prospective regional centers is less than 200 km., they are considered as hinterlands and are permitted to be linked. Conversely, no linkage is established in the latter algorithm. Additionally, the algorithm by Bilen Kazancik and Bilen (2021) utilizes an iterative calculation methodology to achieve 4 hierarchical levels.

In contrast, the study by the Ministry of Industry and Technology (2020) consolidates 7 flow parameters at the district level to derive an integrated flow parameter. Subsequently, these integrated flows transformed into one-way flows according to the generalized degree values derived from flow data. The main difference between this study and that of the Ministry is that this study employs provincial trade data as flow data, while GDP data is used as the primary economic indicator to transform the flows into one-way flows.

3. Results

This study utilizes inter-provincial trade data above 5,000 TL obtained from Entrepreneur Information System of the Ministry of Industry and Technology for the year 2017. Using this data, all the connections are illustrated in the form of a trade network graph in Figure 1. The figure was created using *graph R package*, but it can also be generated using *igraph or tidygraph*. Strong connections are marked by bold lines, while weak connections are represented by light lines. The important centers are placed in the middle of the network, while less developed provinces are located on the periphery.

In Figure 1, Istanbul is at the center of the network, and is surrounded by Izmir, Kocaeli, Ankara, Bursa, Gaziantep, Adana, Denizli, Adana, and Mersin. However, less developed provinces like Artvin, Bayburt, Ardahan, Rize, Karaman are located on the periphery.

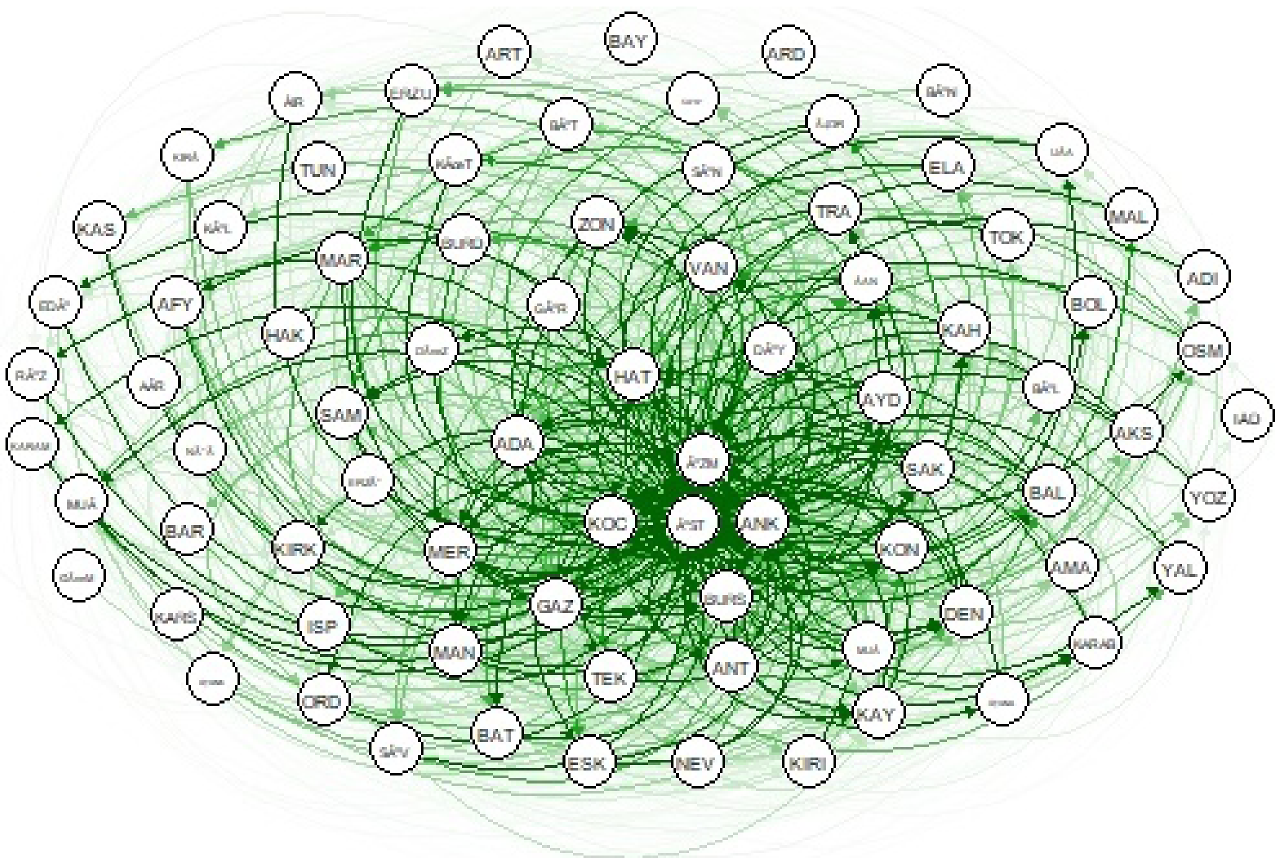

Figure 1: Trade Network Relationships Graph (Source: Generated by the authors)

In order to analyze the relations and centrality level of provinces, Figure 2 illustrates the top 4 supplier provinces for each province. Utilizing the *graph R package*, trade data are represented as-two way and weighted connections, and lines emanating from a province are color-coded to indicate the importance of the linked province in terms of purchasing goods and services. Line colors of red, blue, green and brown represent the rank of top supplier provinces in descending order from first to fourth. The thickness of lines is proportional to the amount of trade, and the size of colored circles indicates the in-degree centrality of the provinces.

In Figure 2, it is evident that Istanbul is at the top of hierarchy, followed by Ankara and Izmir. Additionally, the Black Sea, Eastern and South Eastern Anatolia Regions primarily obtain goods and services from Istanbul. Conversely, Istanbul receives the majority of goods and services from Ankara, and next Izmir, Bursa, Kocaeli and Antalya.

Notably, there are mutual relations between big cities. While Ankara supplies the majority of goods and services to Istanbul, Kocaeli, Izmir and Konya, it receives the most from Istanbul, Izmir, Kocaeli and Bursa. Similarly, Izmir supplies the most to İstanbul, Ankara, Manisa and Bursa while receiving the most from Istanbul, Ankara, Manisa and Kocaeli.

Figure 2 also highlights mutual relations that exist out of the hierarchy. The most prominent two-way strong relations in this category are Istanbul-Ankara, Istanbul-Izmir, Istanbul-Kocaeli, Izmir-Manisa, Adana-Mersin and Sanliurfa-Mardin. This implies the existence of mutual supply-demand chains and inter-provincial complementarity between these provinces.

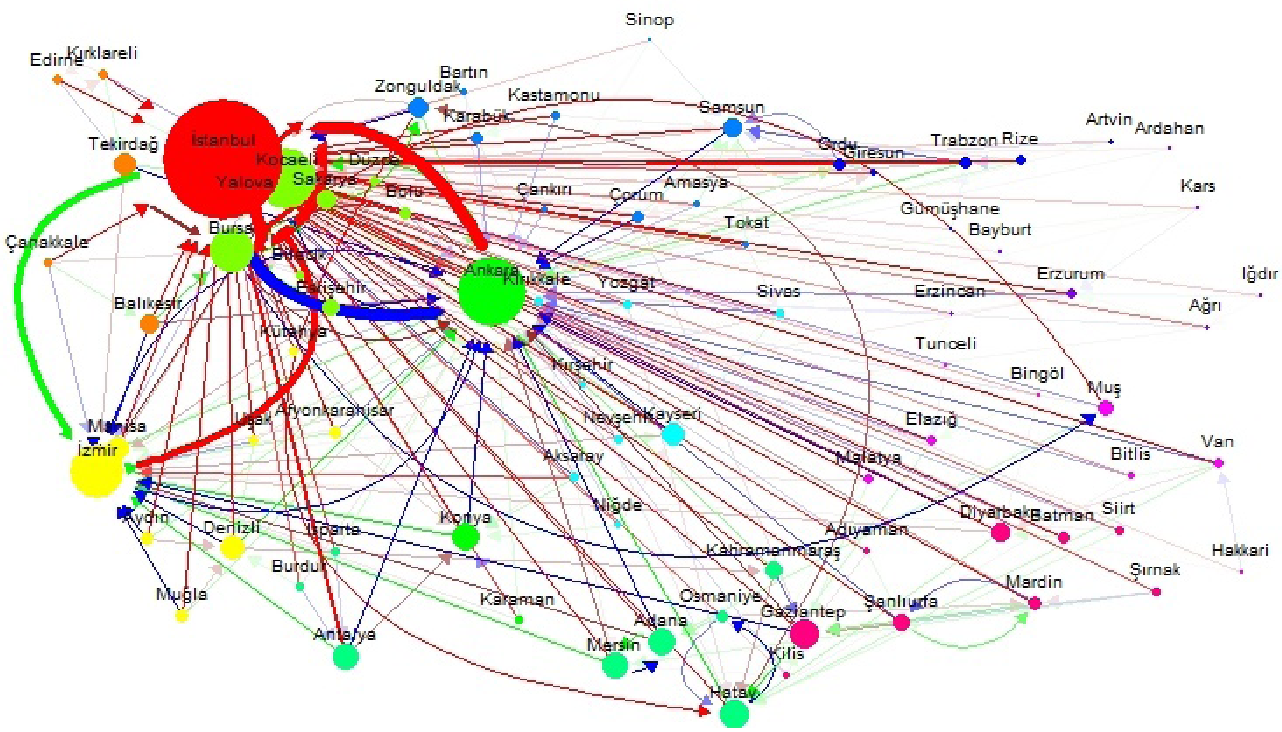

Figure 2: Trade Relations Between Provinces (Source: Generated by the authors)

The strength of the linkages is more pronounced in the western provinces than in the eastern provinces, which is indicative of the regional development disparities between western and eastern provinces. Conversely, Istanbul has strong one-way relations with almost all eastern provinces. Similarly, eastern provinces primarily receive the goods and services mostly from western provinces such as Istanbul, Ankara, Izmir, Bursa, and Kocaeli but their supplies to the west are relatively limited. However, provinces with a high in-degree centrality index have exhibit mutually horizontal relations, rather than one-way linkages.

This suggests that a study on inter-provincial relations should consider both levels in conjunction, rather than focusing exclusively on hierarchy or horizontal relations. To this end, this study incorporates both horizontal and hierarchical levels by taking geographical proximity into account as horizontal relations, while linkage strength in the network is considered as hierarchical relations.

In the algorithm, the centrality index of provinces is represented by their GDP values for the year 2019. The centrality indexes are classified into 5 groups by Jenks natural breaks and their geographical distribution is illustrated in Figure 3. Istanbul has the highest centrality index, followed by Ankara, Izmir, Bursa and Kocaeli. Additionally, provinces in the first 4 groups are designated as potential regional centers.

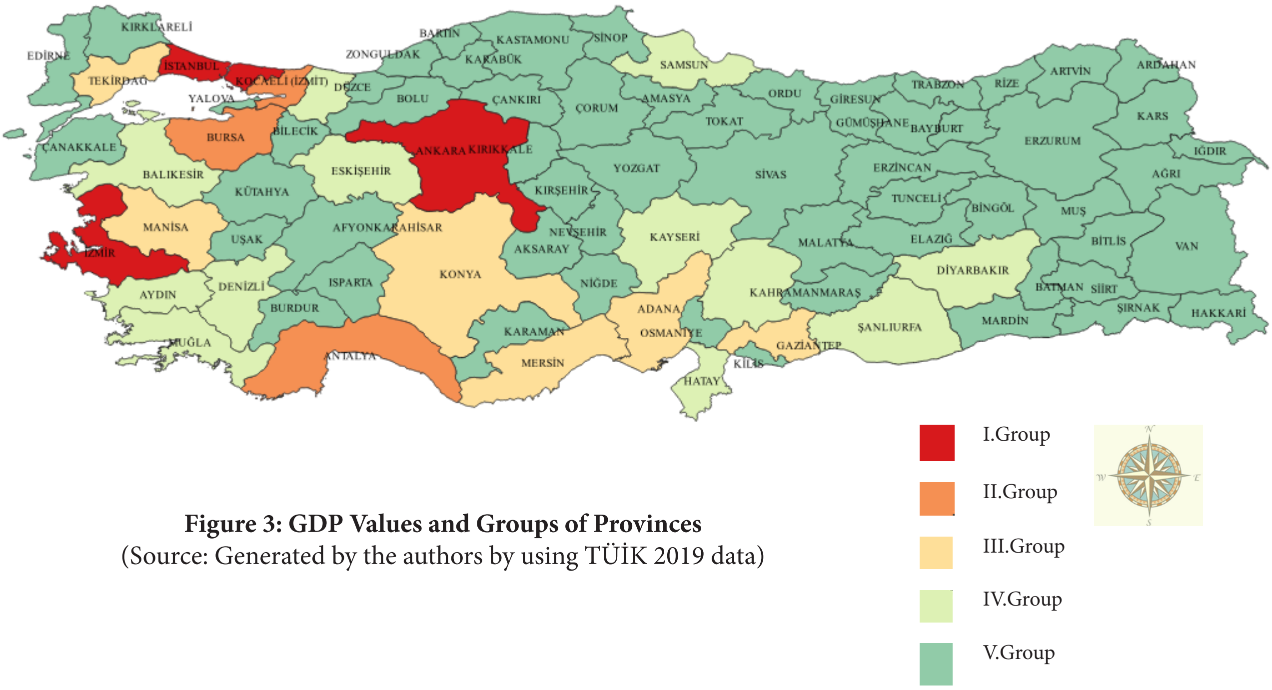

Figure 3: GDP Values and Groups of Provinces
(Source: Generated by the authors by using TÜİK 2019 data)

In the next step, the algorithm employs the weighted data of trade relations to create a hierarchical structure based on their centrality indexes, which is then filtered according to the neighborhood constraint. The results are illustrated in Figure 4, which depicts the primary suppliers for each province.

Notably, Figure 4 reveals some patterns that deviate from expectations. For example, while certain provinces, such as Aydin, Muğla and Mersin, are in the first 4 groups (prospective regional centers), they lack links. On the other hand, certain provinces initially in the 5th group exhibit linkages that attract other provinces. For instance, Zonguldak, which is in the 5th group, supplies the majority of goods and services to Bartin and Karabuk under the neighborhood constraints. Similar cases are observed for Trabzon, Erzurum, Elazig, Malatya and Van.

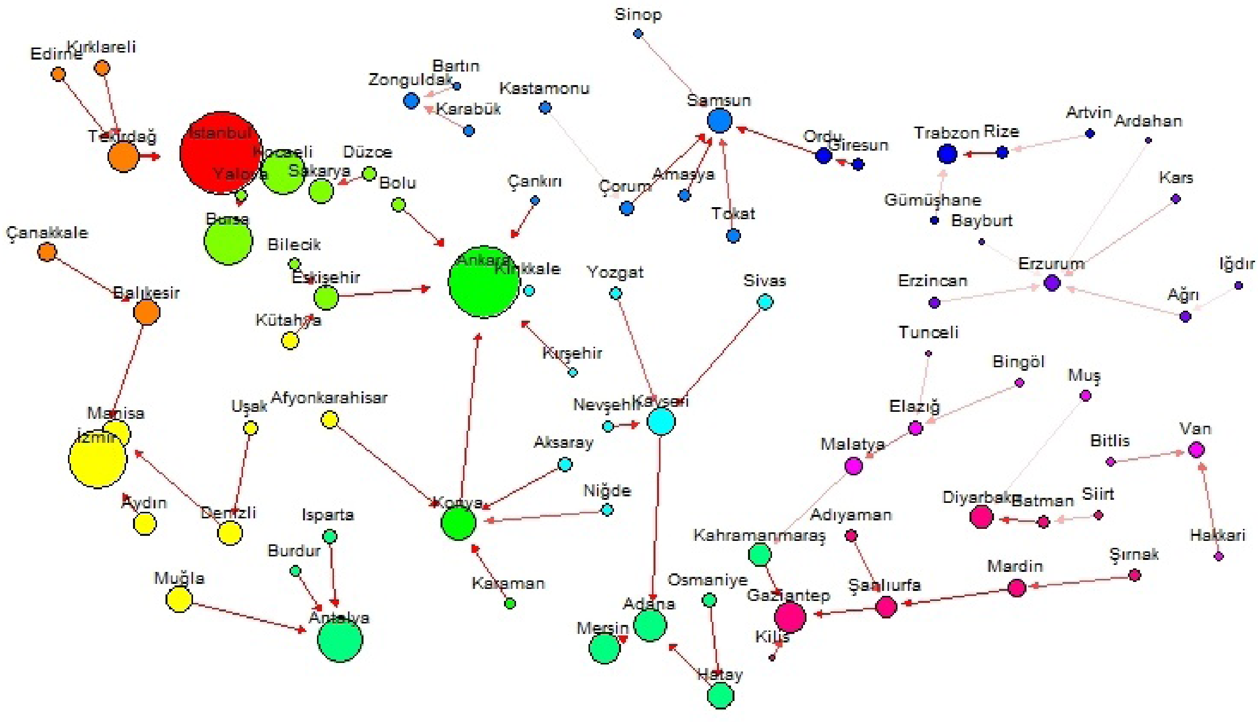

Figure 4: Initial Relations under Hierarchical and Neighborhood Constraints-6. Step of the Algorithm
(Source: Generated by the authors)

In the subsequent step, the algorithm elevates the provinces with 2 or more connecting provinces to a higher level and categorizes them as prospective regional centers. In instances where provinces with 2 or more linked provinces are also connected to another province in the 5th group, then the connected province is also elevated to a higher level and categorized as a prospective regional center. For example, if Tunceli and Bingol is linked to Elazig, but Elazig is also linked to Malatya, both Elazig and Malatya are designated as prospective regional centers.

When the prospective provinces are within a distance of 200 km from one another, the province with the lower centrality index is removed from the group and designated as a hinterland of the other. Conversely, if the distance between the provinces exceeds 200 km, both are recognized as separate regional centers and their connection is severed separately and the linkage is broken. The outcome of these procedures is illustrated in Figure 5, where patterns of hierarchical relationships among the provinces are established.

It can be observed that Tekirdag and Kocaeli are not separated from Istanbul due to their proximity and are instead assigned to Istanbul's hinterland. Similarly, Sakarya is also not separated from Kocaeli, and also Manisa is not seperated from Izmir, Mersin from Adana, Sanliurfa from Gaziantep, and Elazig from Malatya.

In accordance with the distance constraint, Mugla is separated from Antalya and connected to Denizli. Similarly, Eskisehir and Konya are separated from Ankara, Kayseri from Adana, Malatya from Kahramanmaras, and Denizli from Izmir.

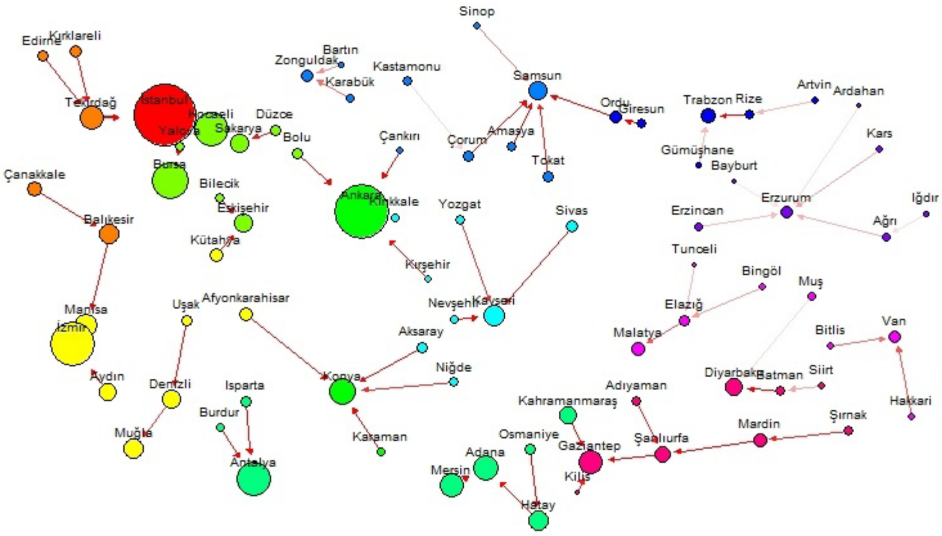

Figure 5: Initial Relations under Distance Constraint-7. Step of the Algorithm
(Source: Generated by the authors)

As a result of the algorithm, the provinces are classified into 18 regions centered around Istanbul, Zonguldak, Ankara, Bursa, İzmir, Eskisehir, Denizli, Antalya, Konya, Adana, Kayseri, Samsun, Trabzon, Erzurum, Malatya, Diyarbakir, Gaziantep and Van, as illustrated in Figure 6.

The algorithm reveals economically integrated regions by preserving hierarchical relations under neighborhood constraints. It must be noted that this cannot be achieved solely by applying network model, as it ignores the geographic proximities and assigns centers and relations independently of location. However, network centrality measures can be effectively utilized to scrutinize place-based impacts on centers and their hinterlands. A comparison between the centers and regions derived from the algorithm and network centrality measures facilitate a better understanding of the effects of location and neighborhoods in regional science and policy.

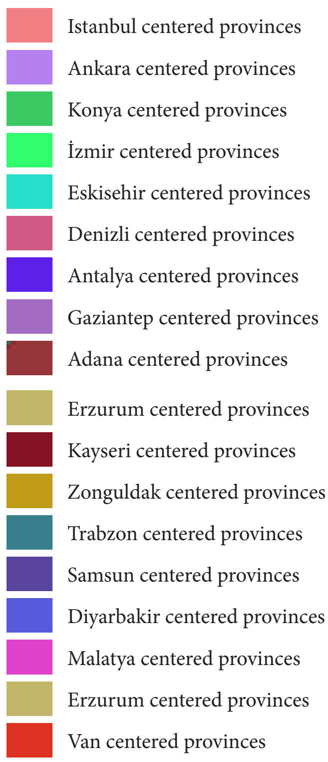

Figure 6: Functional Regions Based on Economic Relations
(Source: Generated by the authors)

For this purpose, Table 2 is constructed with provincial in-degree, out-degree centralities, closeness and betweenness measures. It is noteworthy that provinces with high GDP values are prominent in the ranking of these metrics. This is further supported by the fact that there is a 98.7 percent of correlation between in-degree centrality measure and GDP. The other significant are provided below for each metric.

In-degree centrality measure is utilized to assess the goods and services supplied by a given province to the others. Typically, regional centers exhibit high rankings in this metric. However, this is not always the case for eastern regions. For instance, Trabzon (30th), Van (36th), Erzurum (44th) and Malatya (46th) provinces have low in-degree centrality rankings, despite being classified as regional centers. These provinces are located in less developed regions and possess a low trade potential. Nevertheless, they act as centers for surrounding less developed provinces due to their geographic proximity.

On the other hand, out-degree centrality is used to measure the level of goods and services received by a province from external sources. It is noteworthy that the provinces that are the top suppliers also tend to be the top receivers, and there is a high correlation (99 percent) between these two metrics. This is also directly related to the economic volume of the provinces, as production and consumption are closely linked.

Closeness centrality is a measure of the accessibility of a province. In general, the closeness measure is highly correlated with in-degree centrality, as indicated by the high correlation (95,5 percent) values derived from Table 2. This suggests that the more good and services a province supplies, the more accessible it is. Furthermore, all of the regional centers, with the exception of Zonguldak, rank above above 30th in the closeness metric, which suggests that the closeness measure and the algorithm are aligned and reflect the impact of geographic proximity.

The final metric is the betweenness measure, which detects 8 provinces that serve as a bridge or crossroad in the Turkish trade network. It is noteworthy that some provinces, such as Elazig, Hatay and Kocaeli, despite being smaller than their neighbors, function as a bridge with high betweenness measures. This suggests that the betweenness measure is not a direct result of in-degree or out-degree centrality, but rather a result of other geographical and networking factors.

This conclusion highlights that the role of provinces as a bridge or crossroad cannot be revealed as clearly by a hierarchical approach as it can be by a network approach. This can be considered as a advantage of the betweenness measure over the hierarchical models. As such, the betweenness measure can provide a distinct and verifiable perspective in designing regional policies based on flow or movement of people, goods or money.

Table 2: Centrality Measures and Regional Centers of Trade Network Model (Source: Generated by the authors)

Rank	Provinces	In Degree (*1.000.000)	Provinces	Out Degree (*1.000.000)	Provinces	Betweenness	Provinces	Closeness (*1.000.000)
1	İstanbul*	696,588	İstanbul*	615,224	İstanbul*	6,297	İstanbul*	6.12
2	Ankara*	233,463	Ankara*	239,460	Ankara*	551	Ankara*	2.46
3	Kocaeli	178,550	İzmir*	119,455	Bursa*	158	İzmir*	0.26
4	İzmir*	146,825	Bursa*	97,271	Hatay	157	Bursa*	0.15
5	Bursa*	88,202	Kocaeli	86,838	İzmir*	157	Kocaeli	0.12
6	Gaziantep*	41,994	Gaziantep*	49,910	Antalya*	79	Mersin	0.10
7	Hatay	40,192	Antalya*	49,336	Elazığ	79	Konya*	0.09
8	Adana*	38,128	Konya*	47,854	Kocaeli	79	Diyarbakır*	0.08
9	Konya*	37,735	Adana*	44,234	Adana*	0	Trabzon*	0.07
10	Antalya*	31,546	Mersin	36,763	Adıyaman	0	Antalya*	0.07

Table 2: Centrality Measures and Regional Centers of Trade Network Model (Cont.)

Rank	Provinces	In Degree (*1.000.000)	Provinces	Out Degree (*1.000.000)	Provinces	Betweenness	Provinces	Closeness (*1.000.000)
11	Mersin	30,886	Denizli*	32,922	Afyon	0	Gaziantep*	0.06
12	Denizli*	26,049	Hatay	32,720	Ağrı	0	Erzurum*	0.06
13	Kayseri*	24,631	Kayseri*	29,010	Aksaray	0	Elazığ	0.05
14	Tekirdağ	24,259	Sakarya	26,827	Amasya	0	Van*	0.04
15	Manisa	23,301	Tekirdağ	25,512	Ardahan	0	Batman	0.04
16	Zonguldak*	19,584	Manisa	24,574	Artvin	0	Sakarya	0.03
17	Sakarya	18,229	Samsun*	23,609	Aydın	0	Balıkesir	0.03
18	Samsun*	17,712	Diyarbakır*	21,741	Balıkesir	0	Kayseri*	0.03
19	Balıkesir	17,125	Balıkesir	21,105	Bartın	0	Ordu	0.03
20	Diyarbakır*	16,017	Eskişehir*	19,483	Batman	0	Malatya*	0.03
21	Şanlıurfa	15,145	Şanlıurfa	18,763	Bayburt	0	Manisa	0.02
22	Eskişehir*	15,019	Trabzon*	16,887	Bilecik	0	Eskişehir*	0.02
23	K.maraş	14,608	Zonguldak*	16,134	Bingöl	0	K.maraş	0.02
24	Muş	10,271	K.maraş	15,944	Bitlis	0	Bitlis	0.02
25	Aydın	9,676	Muğla	14,559	Bolu	0	Aydın	0.02
26	Mardin	9,512	Mardin	14,032	Burdur	0	Ağrı	0.01
27	Muğla	9,225	Aydın	13,993	Çanakkale	0	Samsun*	0.01
28	Karabük	7,653	Muş	11,489	Çankırı	0	Rize	0,01
29	Osmaniye	7,353	Van*	11,098	Çorum	0	Adana*	0.01
30	Trabzon*	7,353	Afyon	10,238	Denizli*	0	Denizli*	0.01
31	Afyon	6,749	Erzurum*	9,284	Diyarbakır*	0	Tokat	0.01
32	Bolu	6,537	Elazığ	9,250	Düzce	0	Tekirdağ	0.01
33	Ordu	6,257	Çorum	8,923	Edirne	0	Muğla	0.01
34	Çorum	6,139	Batman	8,889	Erzincan	0	Şırnak	0.01
35	Batman	6,051	Sivas	8,147	Erzurum*	0	Bolu	0.01
36	Van*	5,930	Malatya*	7,924	Eskişehir*	0	Uşak	0.01
37	Yalova	5,857	Ordu	7,760	Gaziantep*	0	Nevşehir	0.01
38	Uşak	5,704	Aksaray	6,902	Giresun	0	Şanlıurfa	0.01
39	Düzce	5,572	Osmaniye	6,765	Gümüşhane	0	Muş	0.01
40	Rize	4,972	Çanakkale	6,744	Hakkari	0	Erzincan	0.01
41	Aksaray	4,930	Uşak	6,396	Iğdır	0	Hatay	0.01
42	Kütahya	4,883	Bolu	6,310	Isparta	0	Sivas	0.01
43	Edirne	4,812	Edirne	6,012	K.maraş	0	Kastamonu	0.01
44	Erzurum*	4,530	Kütahya	5,982	Karabük	0	Iğdır	0.00
45	Kırşehir	4,403	Düzce	5,979	Karaman	0	Afyon	0.00
46	Malatya*	4,401	Karabük	5,948	Kars	0	Kilis	0.00

Table 2: Centrality Measures and Regional Centers of Trade Network Model (Cont.)

Rank	Provinces	In Degree (*1.000.000)	Provinces	Out Degree (*1.000.000)	Provinces	Betweenness	Provinces	Closeness (*1.000.000)
47	Elazığ	4,347	Rize	5,811	Kastamonu	0	Adıyaman	0.00
48	Sivas	4,197	Yalova	5,654	Kayseri*	0	Mardin	0.00
49	Çanakkale	4,170	Kırşehir	5,539	Kırıkkale	0	Yozgat	0.00
50	Karaman	4,149	Isparta	5,464	Kırklareli	0	Çorum	0.00
51	Nevşehir	3,696	Yozgat	5,324	Kırşehir	0	Karaman	0.00
52	Yozgat	3,695	Tokat	5,244	Kilis	0	Düzce	0.00
53	Burdur	3,632	Karaman	5,229	Konya*	0	Artvin	0.00
54	Kastamonu	3,534	Nevşehir	5,146	Kütahya	0	Giresun	0.00
55	Kırklareli	3,285	Kastamonu	4,999	Malatya*	0	Edirne	0.00
56	Isparta	3,082	Adıyaman	4,945	Manisa	0	Osmaniye	0.00
57	Siirt	3,045	Şırnak	4,909	Mardin	0	Isparta	0.00
58	Şırnak	2,950	Giresun	4,586	Mersin	0	Niğde	0.00
59	Bilecik	2,902	Burdur	4,557	Muğla	0	Yalova	0.00
60	Tokat	2,859	Niğde	4,291	Muş	0	Zonguldak*	0.00
61	Adıyaman	2,813	Kırklareli	4,243	Nevşehir	0	Çankırı	0.00
62	Niğde	2,736	Siirt	4,149	Niğde	0	Amasya	0.00
63	Amasya	2,651	Amasya	3,899	Ordu	0	Bilecik	0.00
64	Kilis	2,547	Bitlis	3,713	Osmaniye	0	Siirt	0.00
65	Giresun	2,452	Bilecik	3,244	Rize	0	Kütahya	0.00
66	Çankırı	2,168	Kilis	3,224	Sakarya	0	Karabük	0.00
67	Bitlis	2,101	Çankırı	2,907	Samsun*	0	Burdur	0.00
68	Kırıkkale	1,814	Ağrı	2,801	Siirt	0	Bartın	0.00
69	Bartın	1,804	Bartın	2,566	Sinop	0	Bingöl	0.00
70	Ağrı	1,433	Erzincan	2,282	Sivas	0	Kırşehir	0.00
71	Artvin	1,075	Bingöl	2,134	Şanlıurfa	0	Çanakkale	0.00
72	Erzincan	1,063	Kırıkkale	1,789	Şırnak	0	Kırklareli	0.00
73	Sinop	689	Artvin	1,710	Tekirdağ	0	Sinop	0.00
74	Bingöl	658	Kars	1,438	Tokat	0	Gümüşhane	0.00
75	Kars	533	Sinop	1,414	Trabzon*	0	Aksaray	0.00
76	Iğdır	531	Iğdır	1,223	Tunceli	0	Tunceli	0.00
77	Hakkari	507	Hakkari	1,186	Uşak	0	Kars	0.00
78	Gümüşhane	361	Gümüşhane	1,053	Van*	0	Kırıkkale	0.00
79	Tunceli	184	Tunceli	595	Yalova	0	Hakkari	0.00
80	Ardahan	127	Bayburt	502	Yozgat	0	Ardahan	0.00
81	Bayburt	127	Ardahan	498	Zonguldak*	0	Bayburt	0.00

The distribution of centrality metrics and regional centers displays distinct patterns due to regional characteristics. An examination of centrality measures reveals that almost all eastern regional centers have lower rankings compared to some western provinces that are not designated as regional centers. For example, Kocaeli, which excels in all centrality criteria, is not designated as a regional center due to its location in the hinterland of Istanbul. Similarly, Mersin, Manisa and Tekirdag are evaluated in the same way. Conversely, Erzurum, which is ranked 44th in in-degree centrality, has 6 provinces linked to it, highlighting the importance of regional characteristics and proximity in determining regional centers, rather than relying solely on centrality measures.

In summary, the findings previously discussed demonstrate the complementary relationships between centrality measures and hierarchical models. While both analyses are applied independently, a comparison of their results can reveal the patterns of agglomerations, geographic characteristics and functional distinctions between provinces and regions. Furthermore, the implementation of hybrid models that combine the advantageous features of both approaches can enhance this understanding.

Conclusion

In this study, a combination of network analysis and central place theory was utilized to examine the horizontal and vertical relationships between provinces and regions. Specifically, it analyzes provincial centrality measures, regional centers, and their relative positions in the network based on inter provincial goods and service flows.

Network models are useful in identifying the most strategic nodes and revealing the relationships within the network. In regional science, this can aid in determining the most effective points of intervention and groups. However, these groups are based on solely flows within the network, disregarding geographic proximity. This can result in the inclusion of non-adjacent provinces within the same group. Additionally, centrality measures provide an overall measure of importance within the network, but do not consider spatial factors. As a result, network models alone are insufficient for identifying local centers in less developed regions. To address this, a hybrid model combining network and central place theories is used to determine regional centers and their hierarchical structure.

In this study, the preliminary step is to obtain hierarchical structure from bidirectional flow data. This requires a transformation of bidirectional to unidirectional structure. This structure is obtained in the form of a matrix with ones and zeros, representing whether province-a dominates province-b in terms of provincial centrality indices. Although these indices can be represented by provincial in-degree, out-degree, closeness and betweenness centrality measures of the network model, it is assumed that GDP is the most appropriate data for the indices as it is an economic indicator that is directly related with the scope of this study. The method employed aims to construct regions that maintain geographical integrity by including both centers and their hinterlands. The analysis produced 18 regions, each centered on one of the following cities: Istanbul, Zonguldak, Ankara, Bursa, Izmir, Eskisehir, Denizli, Antalya, Konya, Adana, Kayseri, Samsun, Trabzon, Erzurum, Malatya, Diyarbakir, Gaziantep and Van. These regions are similar to those found in the study “YER-SIS” by the Ministry of Industry and Technology (2020) although the latter study consolidates 7 different flows based on district data, and employs different methods for transforming unidirectional structure. Despite the use of different data sets and settlement units in each study, similar results are obtained, with some provinces (such as Mugla, Mardin, Sirnak, Kastamonu, Muş, and Artvin) being located in different regions in this study.

The study also reveals that in Türkiye, regardless of distance, the strongest relationships for almost all provinces are primarily with Istanbul, followed by large metropolitan areas such as Ankara and Izmir, and centers nearby. This suggests that trade in Türkiye is mainly facilitated by Istanbul, and has a multi-centered structure, with the majority of centers located in the west.

On the other hand, a comparison of the results of the rule-based algorithm with network centrality measures reveals the impact of agglomerations, geographic features and functional differences on the provinces and regions. For instance, eastern regional centers have lower centrality index values than some western provinces that are not designated as regional centers. This is due to the geographic distribution and proximity, and can be easily comprehended through the comparison of both approaches. In conclusion, both network and central place models have their own advantages when it comes to devising regional policies. The simultaneous use of both models provides a more reliable and comparable analysis. The results of a hybrid and rule-based algorithm with constraints were compared with some parameters of the network model, and it was found that this kind of comparison facilitates the detection of agglomerations, regional and relational patterns in the network. The differences in the results of both approaches can be seen as an important signal for further analysis. The proposed algorithm, which combines certain aspects of network and central place theories, is expected to be used in similar spatial studies, such as rule-based functional areas, and can be further improved by incorporating additional constraints and data into network models.

Author Contributions

Dr. Leyla Bilen Kazancık: *Generating the idea for the article, literature review, formulating the article's hypothesis, planning the research method, determining the content and organization of the article, obtaining and processing data, conducting analysis, article writing, reviewing*

Dr. Ömer Bilen: *Generating the idea for the article, literature review, formulating the article's hypothesis, planning the research method, determining the content and organization of the article, obtaining and processing data, conducting analysis, article writing, reviewing*

Ayşe Bilen Acar: *Literature review, determining the content, organization of the article, article writing, reviewing, management and responsibility for the course of organization of the article*

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No potential conflict of interest has been declared by the authors.

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Compliance with Ethical Standards
It has been declared by the authors that the tools and methods used in the Study do not require Ethics Committee Permission.

Ethics Statement
It has been declared by the authors that all the studies used are stated in the bibliography.

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