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Rethinking Space in Production Networks: Network Centrality and R&D Activities in Ankara Defense and Aviation Cluster

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Abstract

The main motivation behind the cluster approach in 1990s is to improve the innovation capacity by means of production networks. This paper presents findings on production networks and innovation activities in Ankara defense and aviation cluster. The network maps show that, inclusion/exclusion to the network and centrality in the network has taken the place of spatial proximity and geographical location. Moreover, the results of the analysis could not confirm the relation between subcontracting networks and R&D activities, but have confirmed the relation between service networks and R&D activities. These outcomes may guide the sector and cluster development strategies.

1. INTRODUCTION

Since 1990s there is a vast literature on clusters, which is seen as an important policy tool in local development. The main motivation in clustering is argued to be improving the innovation capacity through connecting to networks in a highly competitive environment. Especially, following 1990s, many cluster studies focused on network and innovation capacity concepts. Within this context, defense and aviation clusters are based on large leading firms with connection to global production networks that produces high value products.

The production networks established around large leading firms and their suppliers and subcontractors give the basic structure of the defense and aviation cluster [1]. For suppliers and subcontractors, being close to and in relationship with the main contractor offers amenities such as attaining high technology, reaching global markets indirectly and increasing competitiveness. The desire to be close to end user and recipient government institutions is seen to be effective in the location of the defense and aviation industry.

The presence of organized industrial zones, science parks, universities, research institutions, and other related public sector institutions can be counted among the main relevant reason for the defense and aviation industry to locate in Ankara. The reason for choosing Ankara as the field study area is its sector-leading position. In this paper, Ankara is called as ‘Ankara defense and aviation cluster’.

The aim of this paper is to answer two basic research questions constructed on the theoretical framework; (1) Have spatial proximity been reproduced within cluster network relations? (2) Which one does affect the innovation capacity (R&D activities) of firms positively; subcontracting networks or service networks? To answer the research questions, in-depth interviews have been made with 97 subcontracting firms located in Ankara defense and aviation cluster. Furthermore, interviews with 6 main contractor firms have been

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conducted. The interviews with the firms took six months, from September 2014 to March 2015. As an outcome of the interviews, a database has been built compiling information such as subcontracting linkages, service linkages, R&D agreements/joint R&D projects, the R&D supports, R&D expenditures, and skilled employment in firms. The production networks have been scrutinized using network analysis performed by Gephi Program. In addition, the relation between production networks and R&D activities is statistically analyzed.

The paper consists of six main parts. Following the introduction, at second part the conceptual framework of network relations in industrial clusters, network centrality and innovation is considered. Third part presents the method of the field study in Ankara. The results of the subcontracting networks, service networks and R&D networks (agreements/projects and support) analysis are discussed in fourth part. As at fifth part the relationship between networks and R&D activities is scrutinized, at conclusion the overall assessment of the findings and policy implications are discussed.

2. CLUSTER NETWORKING, NETWORK CENTRALITY AND INNOVATION CAPACITY

In 1990s, competitive advantage based cluster concept with reference to Porter [2] came on the agenda. Clustering can be defined as complementarity and cooperation relations formed by firms and associated institutions within a particular area and at a geographic proximity [3]. According to Porter [2], it can be said that the components that trigger clusters are spatial proximity fed from the co-production culture, networks, and low transaction costs arising from geographical location.

Suppliers, customers, competitors, universities, institutions and firms are the main actors of the cluster and gain various advantages with joining the cluster. Studies addressing clusters' positive externalities reveal that firms involved in cluster, compared to firms not included in any cluster, are more competitive, more innovative and more successful [4, 5].

Defense and aviation industry is based on large leading firms that produce high value products and are part of the global production network. In this context, the main contractor firm and its suppliers located around explains the clustering tendency of the defense and aviation industry [1]. Additional studies point out that clustering tendency positively affects the competitiveness of the sector [6, 7]. The high investment costs of large leading firms are resulting at low geographical mobility of the sector [8]. This stability of firms also affects the continuity of the production network and the basic structure established between the main contractor firm and suppliers [9]. Clustering around the leading firm increases the subcontractors' competitiveness by enabling mutual learning, developing skills, and updating enhanced capabilities. At the industry the desire to be close to the government institutions both as the end-user and the purchaser influences the location of the cluster.

The cluster approach is basically described over spatially agglomerated firms and networks between these firms. Closeness of firms located in the same cluster is named as 'spatial proximity'. However, although the clustering approach is basically based on the concept of spatial proximity, spatial proximity is not enough to explain the dynamics of the cluster, and different proximity approaches are come into agenda in cluster studies. Boschma [10] defines five dimensions of proximity; cognitive, organizational, social, institutional and geographical proximity. Yet, distinction is frequently made between organizational and geographical proximity in the literature [10]. While spatial proximity is defined as spatial distance between actors, organizational proximity is related to closeness of actors in the way doing business and the business tradition. Nevertheless, Torre and Rallet [11, 12] state that although spatial proximity is not a necessary condition for the establishment of a relationship between firms, 'organized proximity' is required for effective inter-firm linkages. Organized proximity is defined by formal and informal rules, common beliefs, common knowledge, mutual trust, common interests and common action [13]. With these dimensions, organizational proximity has a close relationship with institutional and cognitive proximity approaches [10].

Networks are at the core of organized proximity, and space can be re-interpreted in networks [10]. Networks are not only a mechanism for coordinating relations, but also seen as a tool through which information is transferred. The independence and self-reliance level of the actors on the network is considered as significant and control on the flow of information is not associated with the geographic location but with the place on the network, as the place in the network distinguishes the organized proximity [10].

Unlike the geographical position, the network position of actors in the cluster can be explained by network analysis. On the network, it is possible to take part at nodes where all relations coalesce, be in a central position on the network, and build bridges with third parties not connected to the network. Centrality and strong links presented on network maps can be seen as the representation of organized proximity.

As clustering and networks provide the necessary environment for information production and sharing, they are associated with innovation capacity. At the innovation process, information and the production of knowledge surpass, and also tacit knowledge embedded to local becomes as important as codified knowledge. In the linear innovation approach the production of knowledge is directly associated with R&D activities. In his endogenous growth study Romer [14] refers to technological innovation as a source of direct growth, related with the amount of resources allocated to R&D activities. Highly educated and skilled workforce, technological knowledge that can be codified, and high value R&D expenditure are considered to be the main inputs of R&D activities. The linear innovation approach offers a simple and powerful explanatory, and therefore is popular among both the scientific community and policymakers [15,16]. In the approach knowledge generated is largely codified knowledge. The encoded knowledge can spread long distances with relatively low cost and is not distracted by distance. However, all knowledge cannot be fully codified, and the encoding of information in specific cases may be very costly or even impossible. In particular, in clusters, R&D is subject to variation among the firms, and innovation produced elsewhere can also be adapted to the cluster. In addition to the R&D activities in firms, proximity within cluster, production environment, local synergy and the conditions associated with the network plays an important role in the realization of innovation processes [15].

In the defense and aviation industry, in the process of innovation, codified knowledge and high cost R&D investments become important. In this context, the large contractor firms are the main actors leading the production of knowledge, its dissemination between different actors, and hence the innovation process in which they provide important support to the cluster environment [1]. The main contractor firms make a great effort for the codification of knowledge in order to ease the regulation and transfer of knowledge and technology to sub-contractors in the cluster. To work with codified knowledge based on R&D improves the quality of communication between different actors, the quality of the product, and prepares the ground for continuous innovation. The leading prime contractors can act as to regulate the input and output of new knowledge and technologies in the cluster; they fulfil the function of being a hub to knowledge in process of access to external sources of knowledge, enable the re-codification of external knowledge to be used in the cluster, and provide the dissemination of knowledge suitable for cluster. In other words, the role of the main contractor may be assumed to be spreading the new knowledge acquired from outside sources to the subcontractors which work together in cluster [1].

3. ANKARA DEFENSE AND AVIATION CLUSTER: FIELD STUDY METHODOLOGY

Defense and aviation industry is characterized by its concentrated and network structured supply chain, which brings together the agglomeration processes. The main actors of the sector are the large firms that are the global players and attract the SMEs to the region. Nearly 70 % of all defense and aviation industry firms in Turkey are located in Ankara, including 6 out of 11 defense and aviation industry firms that are listed among the first 500 biggest industrial enterprises of Turkey. Organized industrial zones, science parks, universities, research institutions and relevant government agencies constitute an important infrastructure for the clustering of the sector in Ankara. The field study is conducted in the metropolitan area of Ankara, where the firms and the multi-actor networks are concentrated.

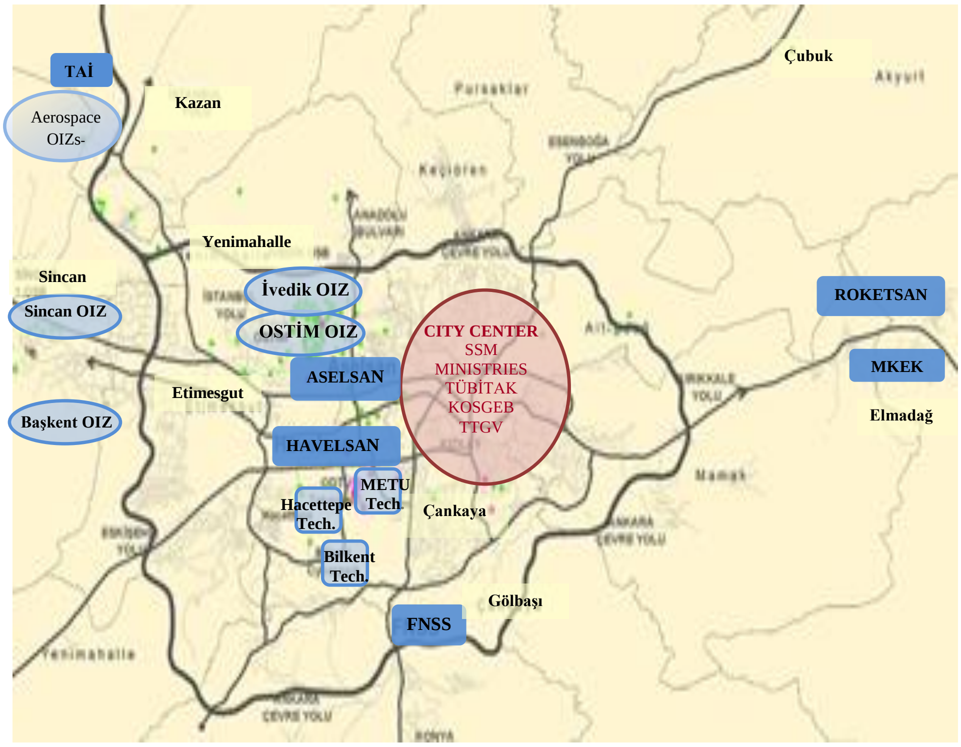
The universe of the study area is 247 subcontractors located in Ankara, which of all have been reached in the research process. 97 of the subcontractors (39.27%) responded to the survey, while the remaining 150 firms did not respond (Table 1).

Table 1. *Number of surveys according to sub-regions*

	Completed questionnaire	Firms with no response	Total firms reached	Response ratio of firms (%)
YENİMAHALLE	52	60	112	46.43
Ostim OIZ	35	21	56	
İvedik OIZ	11	33	44	
Other (Yenimahalle)	6	6	12	
ÇANKAYA	22	76	98	22.45
ODTÜ Technopark	12	55	67	
Bilkent Technopark	3	0	3	
Hacettepe Technopark	1	0	1	
Other (Çankaya)	6	21	27	
SİNCAN	14	3	17	82,35
Sincan OIZ (1. OIZ)	8	1	9	
Başkent OIZ	4	0	4	
Other (Sincan)	2	2	4	
GÖLBAŞI	1	4	5	20.00
Gazi Technopark	0	2	2	
Other (Gölbaşı)	1	2	3	
KAZAN	6	4	10	60.00
AKYURT	1	3	4	25.00
ELMADAĞ	1	0	1	100.00
ANKARA Total	97	150	247	39.27

The sub-regions in the field study are based on the districts of Ankara where defense industry is agglomerated. The organized zones such as OIZs and Technoparks in the districts are mentioned by their name in the study (like Ostim OIZ). The reason why Technoparks and OIZs are taken as separate nodes and defined as separate sub-regions in network analysis is the differentiation of the qualifications of the firms involved in these aggregations. While OIZs have low-tech, subcontracting production companies, technoparks have technology-based companies that support the software infrastructure of the industry. In particular, the location of subcontractors in Ankara is affected by the main contractor's location choice and location policies. While subcontractors are located at OIZs near the main contractors, companies located in teknoparks are close to universities and to Çankaya district, the service delivery center of Ankara (Map.1). The scattered industries, on the other hand, are defined by the name of the district where it is located.

The survey has been carried out with the responding 97 subcontractors between September 22, 2014 and March 31, 2015, and completed in six months. A questionnaire has been transmitted to the 247 firms, information has been given about the research by face to face interviews, firms has been reminded of the survey by phone and e-mail, but mainly originating from the needs of high security in the sector, the rate of responds remained at 39.27%. The long duration of the field study, is the result of difficulty in establishing contact with firms, assuring the firms to answer the questionnaires, monitoring the responds of the firms etc.



***Map 1.** Location of main contractors and major agglomerations in Ankara defense and aviation cluster*

The questionnaire applied to firms includes questions related to subcontracting, service and R&D linkages (the number of firms) and R&D activities (R&D expenditures and R&D personnel) of both the main contractors and subcontracting firms. The cause of handling subcontracting, service and R&D networks separately is their different potentials, the differentiation of their linkage behaviors in the network, and the differentiation of the meaning of spatial proximity in these types of networks. The agglomeration of the firms in Ankara metropolitan region has been decisive while identifying the sub-regions for network analysis. The location of the subcontractors in Ankara is affected by the main contractor's location choice and by the location policies regulating industrial zones.

There are six main contractors operating in the cluster. MKEK, operating in the machinery and chemical industry, is a state institution established in 1950. ASELSAN, a Turkish Armed Forces Foundation Development Corporation, is founded in 1975 in defense electronics sector. Sharing the same status, HAVELSAN operates in the field of information technologies and systems, TAI operates in the aviation industry, ROKETSAN operates in the field of rocket and missile systems and the only private firm FNSS whose activities are in the field of land combat systems is established in the 1980s.The outstanding districts in which the sector in Ankara has agglomerated are Yenimahalle, Çankaya, Sincan, Kazan, and the regulated industrial areas, such as Ostim OIZ, İvedik OIZ, METU Technopark (Table 1). In the network analysis, main contractors (ASELSAN, HAVELSAN, FNSS, MKEK, TAI, ROKETSAN) and major agglomerations in Ankara (Ostim OIZ, İvedik OIZ, Sincan 1st OIZ, Başkent OIZ, ODTÜ Technopark, Bilkent Technopark, Hacettepe Technopark, Kazan, Çankaya, Yenimahalle, Etimesgut, Gölbaşı, Çubuk, Elmadağ, Sincan) are represented with dots. Through the defined sub-regions, production networks are analyzed in three sub-categories such as, subcontracting, service and R&D linkages.

All network analyses are made using the Gephi Program, an interactive exploration and visualization platform for complex systems, dynamic and hierarchical networks. For the evaluation of the networks in Gephi Program, various statistical measurements are used to determine the location of sub-regions on the network, such as in-degree, out degree, modularity and Eigenvector centrality.

In degree and out degree values give the strength of linkages in the network. The modularity analysis visualizes nodes with more powerful connections with each other as a neighborhood. In modularity analysis, although nodes in the neighborhoods assigned are strongly connected to each other, some of these nodes can also build strong relationships with other neighborhoods [17]. In other words, a node in the network can be assigned to multiple neighborhoods.

At Eigenvector centrality analysis, Eigenvector is determined according to the assumption that the importance of a node is proportional to the sum of importance of its neighboring nodes. The Eigenvector centrality value is calculated according to the weight of the nodes in the neighborhood unit and the distance between nodes [18].

Graphics layout algorithms are used for the visualization of network analysis in Gephi Program, which intend to locate the edge into the given area in the best way [19]. Fruchterman-Reingold algorithm, where nodes are represented by steel rings and the edges are springs between them, is used at the visualization of network analysis in the article. But the analysis does not use actual physical spring force accounts. In addition, instead of implementing the attractive and repulsive forces in real systems a simpler model is used, as forces are calculated for all the edges and only edges connected attract each other [20].

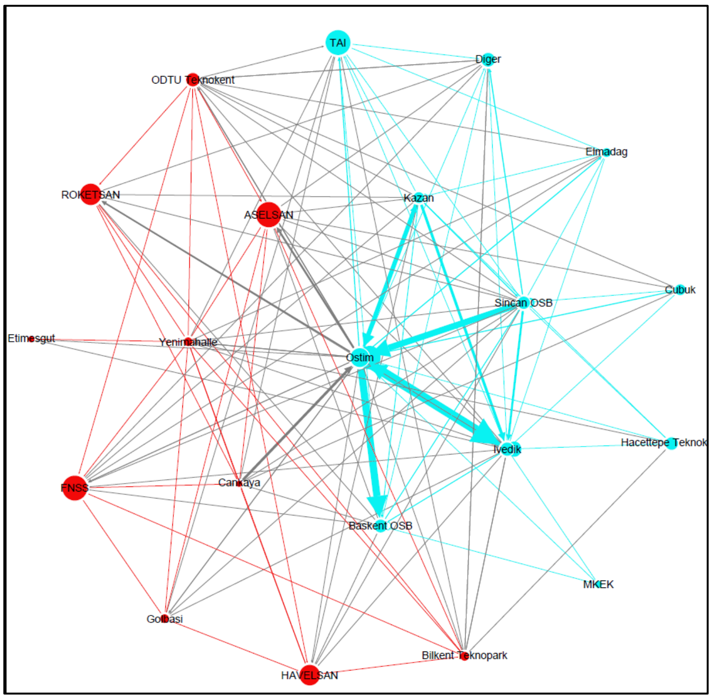
Using firms' maximum number of linkages information from Edges Table, the most intense linkages are represented as thickest connections in the network analysis. At processing the data set of sub-regions in Gephi Program, Eigenvector centrality value is represented by disc size, and Modularity represents the contiguity of most intense network relations by colors. Fruchterman-Reingold algorithm is used in the visualization of the centrality analysis of the data set. In the circular symmetry, strongest firms (based on highest relationship values and highest number of connections) are located at the center, and the rest is pushed to the periphery. In the algorithms the concept of space is re-interpreted and 'spatial proximity' is redefined as 'organized proximity'. Thus, in production networks the importance of location in the network overtook the role of geographical location. Gephi Program is preferred in the study as its Fruchterman-Reingold visualization is a simple and operational method to reposition actors in networks. Furthermore, its statistical analysis gives effective outputs.

4. ANKARA DEFENSE AND AVIATION CLUSTER NETWORK ANALYSIS

The network analysis explores the subcontracting networks, service networks, R&D networks (agreements/projects and support) among the main contractors, supplier firms and relevant institutions located in the Ankara Metropolitan Area.

4.1. Ankara defense and aviation cluster subcontracting network analysis

For which main contractor firms they produce and how many firms there is at each sub-region have been asked to all 97 firms interviewed. The visualized results of the Fructerman-Reingold algorithm of the subcontracting network analysis based on the relationship matrix formed by the firm relation numbers are presented in Map 2.



Map 2. *Subcontracting network map of Ankara defense and aviation cluster; Fruchterman-Reingold visualization*

In Ankara subcontracting network analysis, 21 nodes are analyzed. The network map shows Ostim OIZ in the center with the highest level of linkages. 9 different nodes work as subcontractor of Ostim OIZ, which has subcontracting agreements with all other 20 nodes. Thus, it has the highest value of total connection number of 29 (Table 2). İvedik OIZ also do subcontracting work for all nodes, however, its total subcontract connection number is 26 bonds. Ostim and İvedik OIZs are the two leading subcontracting nodes and there are strong and mutual relations between them. They are followed by Sincan 1st OIZ, Yenimahalle, Kazan, and Başkent OIZ with frequent subcontracting linkages between them (Map 2).

As the main contractor firms outsource their work but do not take any subcontracting, the number of its out degree appears to be zero (0). TAI, ASELSAN and FNSS offers subcontracting work to 12 nodes (Table 2; Map 2). This number is 10 for ROKETSAN and HAVELSAN, as for MKEK it decreases to 3. As Eigenvector centrality is assigned by the number of in degree, the centrality value of TAI, ASELSAN and FNSS are the highest values in the network, which are close to 1. Hence, the diameters of the disk they are represented by are the largest in the network. Among the main contractor firms, MKEK's Eigenvector centrality value is the lowest (0,316) (Table 2). As the main contractor's Eigenvalue centrality is high they are represented with relatively large disks in Map 2. However, as the total linkages of these firms are relatively low, they are located at the periphery in the network map. ASELSAN, differs from other prime contractors, due to the intensity of linkages and is located closer to the center of the map (Map2).

In subcontracting network map, red and blue colors give the modularity (Map 2; Table 2). The main contractors and the group of Bilkent and ODTÜ Technoparks, are represented in red (Map 2). The group that contains all OIZs and TAI, which is the prime contractor, is represented by blue (Map 2). Actors represented with same colour in subcontracting network map also act same within their subcontracting linkages.

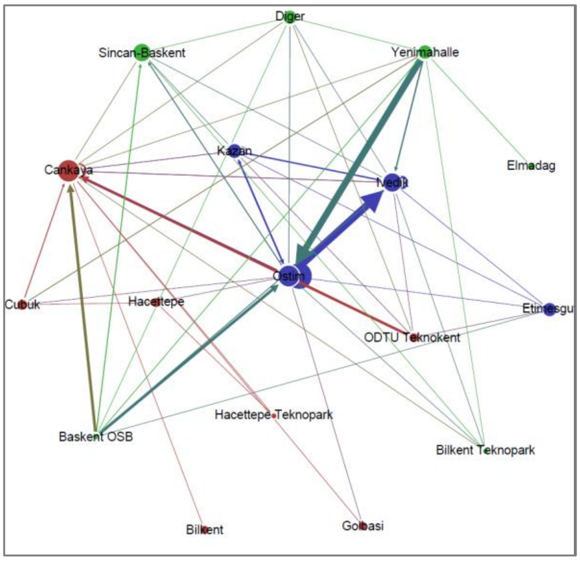
In the network analysis the sub-regions are located on the network map not according to their geographic location, but according to their relationships. The network map brings a new dimension to the discussion of space and spatial proximity. The power of relations overcomes the spatial locations, and thus the firms at Ostim and İvedik OIZs, Sincan 1st OIZ, Başkent OIZ and Kazan can be seen within the same distance in the network map. Moreover, the subcontractors located at Ostim OIZ, are closer to ASELSAN rather than other main contractor firms, despite its spatial positioning (Map 2).

Table 2. *Statistical results of subcontracting network analysis in Ankara defense and aviation cluster.*

	In-Degree	Out-Degree	Degree	Modularity class	Eigenvector centrality
Ostim OIZ	9	20	29	0	0,759
İvedik OIZ	6	20	26	7	0,550
Başkent OIZ	6	11	17	1	0,533
Sincan OIZ	6	17	23	7	0,516
Kazan	5	12	17	4	0,458
ODTU Technopark	6	9	15	5	0,554
Bilkent Technopark	4	8	12	6	0,386
Hacettepe Technopark	6	0	6	6	0,523
Akyurt	5	1	6	0	0,457
Elmadağ	4	5	9	3	0,384
Gölbaşı	4	4	8	2	0,378
Çankaya	3	8	11	2	0,284
Yenimahalle	4	14	18	2	0,378
Etimesgut	3	0	3	2	0,290
Sincan	6	7	13	7	0,566
TAI	12	0	12	3	0,987
ASELSAN	12	0	12	4	1,000
ROKETSAN	10	0	10	5	0,856
HAVELSAN	10	0	10	2	0,825
FNSS	12	0	12	6	0,987
MKEK	3	0	3	1	0,316

4.2. Ankara defense and aviation cluster service network analysis

The service networks of Ankara defense and aviation cluster offer a different structure compared to the subcontracting networks. In the network analysis of the service linkages Ostim OIZ is located at the center with the highest level of linkages. The firms at Ostim OIZ provide services to 10 nodes located in the network, while they receive services from 11 different nodes (Table 3). Thus, the degree value of it at the highest level with 21 linkages it is located at the center in the map. Moreover Ostim OIZ has the most intense service linkages respectively with İvedik OIZ, Yenimahalle, Çankaya, Başkent OIZ, ODTÜ Technopark and Kazan (Map 3).



Map 3. *Ankara defense and aviation cluster service network map; Fruchterman- Reingold visualization.*

At Çankaya the degree value in service network analysis is the second highest. The highest value of the in-degree among all nodes causes Çankaya to have the highest Eigenvector centrality (Table 3; Map 3). In other words, Çankaya can be seen as the service delivery center of Ankara defense and aviation cluster. Ostim OIZ and İvedik OIZ follow Çankaya in Eigenvector centrality. On the other hand, they are the sub-regions where service demand is concentrated. In the service network map, METU Technopark also appears to have an important position.

Modularity of closeness in network describes Ostim, İvedik, Kazan, Sincan as one group, which is represented by blue color and Çankaya, Çubuk, ODTÜ Technopark, Hacettepe Technopark and Gölbaşı as another group which is represented by red color on the service network map (Map 3, Table 3). Modularity groups, reflect the 'organized proximity' between the sub-regions.

Table 3. *Statistical results of service network analysis in Ankara defense and aviation cluster.*

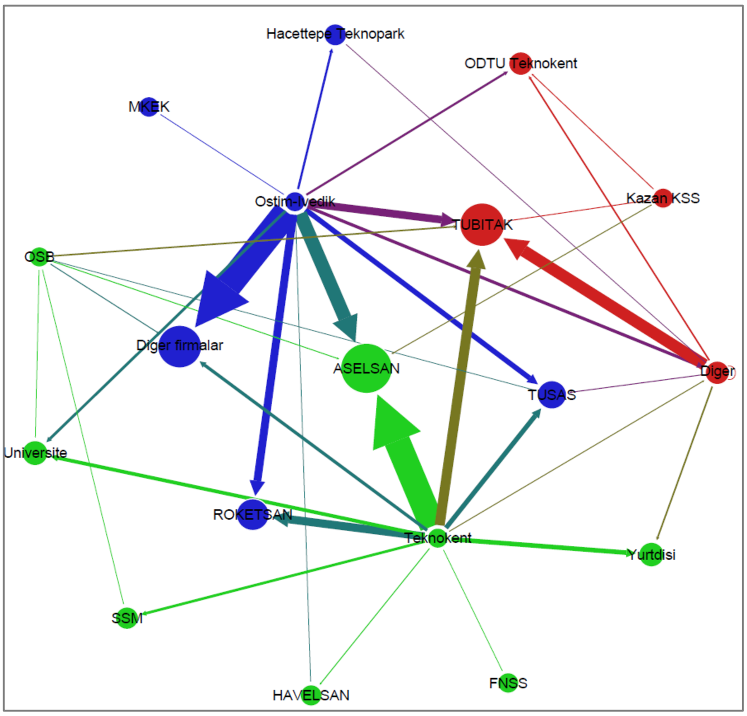
	In-Degree	Out-Degree	Degree	Modularity class	Eigenvector centrality
Ostim OIZ	10	11	21	1	0,961
İvedik OIZ	8	7	15	1	0,802
Sincan OIZ	7	0	7	0	0,751
Başkent OIZ	0	7	7	0	0,000
Kazan	4	6	10	1	0,538
ODTÜ Technopark	2	7	9	2	0,236
Hacettepe Technopark	3	0	3	2	0,250
Bilkent Technopark	0	5	5	0	0,000
Gölbaşı	1	1	2	2	0,189
Çankaya	12	7	19	2	1,000
Yenimahalle	6	7	13	0	0,512
Etimesgut	5	0	5	1	0,500
Çubuk	2	4	6	2	0,300
Elmadağ	1	0	1	0	0,102
Sincan	5	3	8	0	0,498

4.3. Ankara defense and aviation cluster R&D agreement / R&D projects network analysis

In the network analysis, the R&D agreements/projects that the subcontractor firms have made with the main contractors and institutions within last 3 years are analyzed. As the sub-region classification used in both subcontracting network analysis and services network analysis is not suitable. 15 sub-regions are defined in subcontracting and service networks. Since the number of R&D agreements/projects in the Ankara defense and aviation cluster is low, a number of predefined sub-regions have been combined in R&D networks to create a significant number of sub-regions. Ostim and İvedik OIZs are considered as a single sub-region because of their numerous defense and aviation firms, and their spatial and organizational closeness to each other. All other OIZs are defined as one group and are represented by one node in the network analysis. Technoparks are defined as one sub-region. While all the other scattered firms in all the districts are defined as a sub-region, Kazan is called as a separate sub-region especially because of its number of firms with R&D agreements/projects. Thus, the number of sub-regions in R&D network analysis has been reduced from 15 to 5. Another reason for limiting the number of sub-regions to 5 in R&D networks is that involvement of the main contractors and related institutions in R&D networks as separate nodes rises the number of nodes analyzed which increases the level of confusion. Consequently, a new classification of five groups is used in the R&D agreements/projects network analysis; 1) Ostim-İvedik OIZs, 2) other OIZs, 3) Technoparks, 4) Kazan, 5) firms scattered in other areas. Other nodes represent the main contractors (ASELSAN, HAVELSAN, FNSS, MKEK, TAI, ROKETSAN), and institutions (TÜBİTAK (The Scientific and Technological Research Council of Turkey), SSM (Undersecretariat for Defense Industries), universities, etc.) (Map 4).

Ostim-İvedik OIZs and Technoparks are the two sub-regions where the firms with most R&D agreements in the sector are agglomerated. Kazan, on the other hand has a small number of R&D agreement near to null (Table 4; Map 4). The main contractor, which the firms made most of their R&D agreements/project with, appears to be ASELSAN (Table 4). It is observed that the firms located in Ostim-İvedik and in Technoparks have intense R&D agreement/ project linkages with these main contractors (Map 4).

R&D agreements/projects are made with TÜBİTAK, universities, ODTÜ and Hacettepe Technoparks, SSM, other institutions and foreign firms/institutions. Within these institutions TÜBİTAK has the most frequent relations. As the five sub-regions have R&D agreement with it, its centrality value is 1.0 (Table4).



Map 4. *Ankara defense and aviation cluster R&D agreements/ projects network map; Fruchterman-Reingold visualization.*

The second most intense linkages in R&D network are established with the universities. Studies addressing innovation and R&D activities show that the main sources of knowledge are the universities [3]. However, studies reveal that universities in Turkey don't stand out as leading players in the innovation process [4,5]. Although the development of aviation and defense industry is driven by innovation processes based on scientific knowledge and R&D activities, universities do not stand in a central position in Ankara. Even though universities come second at R&D projects/agreements, their linkages are only with three of the five sub-regions, and the number of the linkages (agreements) is quite low (Table 4; Map 4). Thus, the Eigenvector centrality of the universities is far behind TÜBİTAK's.

Table 4. *Statistical results of R&D agreements/ projects network analysis in Ankara defense and aviation cluster.*

	In-Degree	Out-Degree	Degree	Modularity class	Eigenvector centrality
Ostim-İvedik OIZs	0	139	139	0	0.0
Other OIZs	0	10	10	2	0.0
Technoparks	0	126	126	2	0.0
Kazan	0	6	6	1	0.0
Others (firms scattered in other districts)	0	33	33	1	0,0
TAI	22	0	22	0	0. 890
ASELSAN	80	0	80	2	0.989
HAVELSAN	3	0	3	2	0.021
ROKETSAN	31	0	31	0	0.690
MKEK	1	0	1	0	0.011
FNSS	1	0	1	2	0.011
TÜBİTAK	62	0	62	1	1.000
Universities	13	0	13	2	0.310
ODTU Technopark	9	0	9	1	0.790
Hacettepe Technopark	5	0	5	0	0.690
SSM	6	0	6	2	0.021
Other institutions	60	0	60	0	0.031
Abroad	12	0	12	2	0.690

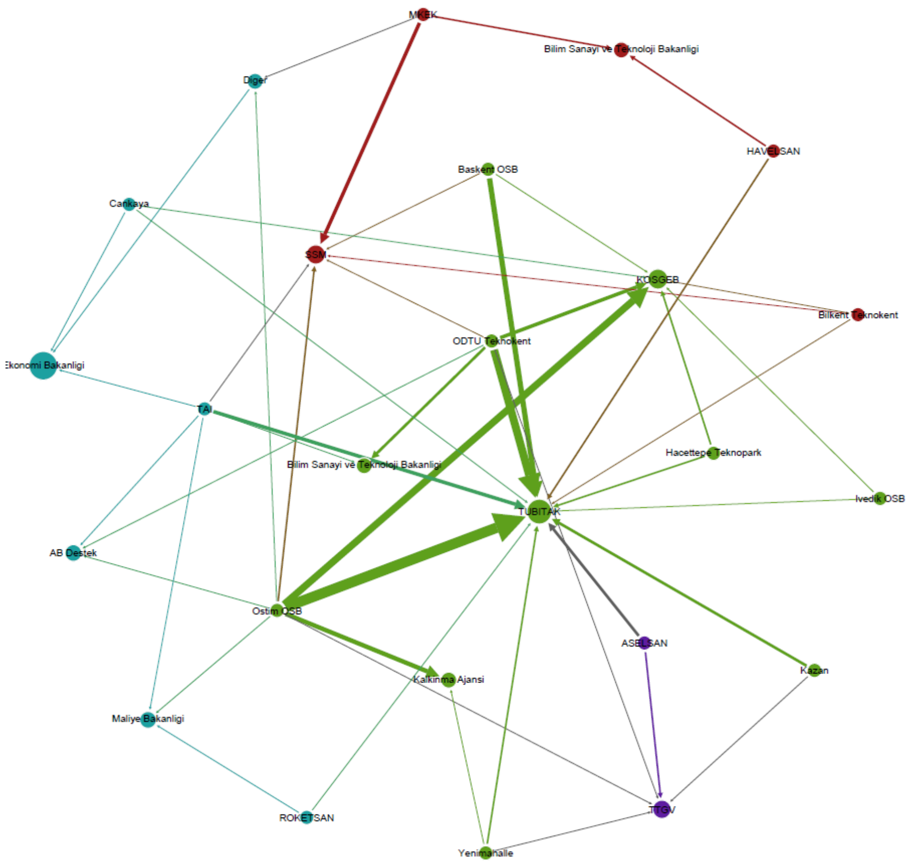
It can be said that the R&D agreement signed with the ODTÜ and Hacettepe Technoparks are more than the R&D agreements with universities (Table 4). Although the innovative firms are located in university technoparks, these firms seem to be lacking intense linkages with the university in Turkey. On the other hand, SSM, which is seen as the most effective institution in the defense and aviation industry, fall behind other institutions at the amount of linkages, not conducting direct R&D processes and thus R&D projects and agreements.

Network analysis of R&D agreements/projects in Ankara shows that in the sector SME's established significant R&D relationships and R&D partnerships with main contractors. In other words, the responsible and navigating firms of innovation and technology in the sector are the main contractors. Moreover, the knowledge source of main contractors in Ankara defense and aviation cluster is the big companies abroad. Another important result that can be extracted is that TÜBİTAK is the key institution in R&D agreements. The relationship with the universities, however, is limited as it is also evident in other sectors in Turkey and the development of this relationship is an important policy area for economic development and innovation.

4.4. Ankara defense and aviation cluster R&D support network analysis

The leading institutions that give R&D support to Ankara defense and aviation cluster are; SSM, TÜBİTAK, Ministry of Finance, Ankara Development Agency, KOSGEB (Small and Medium Business Development and Support Administration), TTGV (Technology Development Foundation of Turkey), Ministry of Science Industry and Technology and the Ministry of Economics. TÜBİTAK has a core role among the institutions that financially support R&D (Map 5).

In network analysis it is observed that 13 of the 14 nodes received R&D support from TÜBİTAK followed by KOSGEB and SSM. MKEK has established the most powerful R&D support linkages with SSM. MKEK is followed by Ostim OIZ in intensity of linkages. The subcontractor sub-regions with R&D support from SSM are Başkent OIZ, ODTÜ Technopark and Bilkent Technopark (Map 5; Table 5). Ostim, İvedik and Başkent OIZs and ODTÜ, Bilkent and Hacettepe Technoparks receive support from KOSGEB. It is observed that technoparks and TÜBİTAK, SSM and KOSGEB that have intense R&D support linkages have also established strong overall relationships (Map 5).



Map 5. *Ankara defense and aviation cluster R&D support network map; Fruchterman-Reingold visualization.*

Technoparks and OIZs receive R&D support from various institutions. While the main contractors benefit relatively more from the R&D supports in the sector, they have R&D support linkages with fewer institutions (Map 5). It is noticed that TÜBİTAK, SSM and KOSGEB have established strong linkages with Technoparks.

5. THE RELATIONSHIP BETWEEN PRODUCTION NETWORKS AND R&D ACTIVITIES IN ANKARA DEFENSE AND AVIATION CLUSTER

Innovation capacity is largely based on scientific, codified knowledge depending on R&D activities in defense and aviation industry. In the paper two indicators of the R&D activities are; “the proportion of R&D expenditure in total expenditure” and “the proportion of qualified R&D personnel (master's and doctoral graduates) within total employees”.

The analysis scrutinizes the relationship between networks and R&D activities, and its differentiation according to the type of network and whether the R&D activities related indicators varies according to the sub-region or not. Networks are considered in two headings; “subcontracting network” and “service network” that encloses R&D networks. The frequency of production networks is measured by the number of firm’s linkages with other firms located in Ankara.

The rate of firms with R&D expenditure in the sector is about half the total of 97 interviewed firms (55.7%). 43 firms indicated that they don’t have allocated budget to R&D. When R&D expenditure is considered to be the main indicator of the competitiveness, the 44.3% ratio of firms (43 firms) with no R&D expenditure should be considered as an area to be evaluated and dealt. At the majority of firms (66.7%) the proportion of the total R&D expenditure remains below 25%.

In Ankara the proportion of firms with no R&D expenditure is the highest in İvedik OIZ (63.6%). Sincan 1st OIZ (50.0%) and Ostim OIZ (48.6%) follow İvedik OIZ. High R&D expenditure rates are observed in ODTÜ and Bilkent Technoparks. The sub-regions that have the highest rate of firms without any master or doctoral degree are again İvedik OIZ, which is followed by Ostim OIZ and Yenimahalle. Similar to R&D expenditures, the proportion of qualified personnel is observed to be the higher in Technoparks. The second highest ratio of R&D personnel is at Çankaya. Technoparks and Çankaya are sub-regions where R&D expenditure and R&D personnel are concentrated, while OIZs, remain behind.

Some studies in literature emphases the relationship between firm networks and R&D activities. The paper scrutinizes the relation between subcontracting network, service network and R&D activities in Ankara defense and aviation cluster. R&D expenditure and R&D personnel ratio are discussed as indicators of R&D activities and their relation to subcontracting network and service network is questioned.

5.1. The relationship between subcontracting network and R&D activities

Subcontracting linkages are common in production networks in Ankara defense and aviation cluster and the rate of the firms with no subcontracting linkages is only 22.7% (Table 5). Table 5 shows that there is no statistically significant relationship between the subcontracting network and R&D expenditure. Firms with no R&D expenditure may have both low and high subcontracting linkages intensity (Table 5). The results reveal no clue for a relation between subcontracting network and R&D expenditure in Ankara.

Table 5. *Subcontracting network and R&D expenditure in Ankara defense and aviation cluster*

The ratio of R&D expenditure in the total		Intensity of subcontracting Network			Total
		None	Low	High	
None	Number	11	21	11	43
	%	25,6	48,8	25,6	100,0
Low	Number	5	18	13	36
	%	13,9	50,0	36,1	100,0
High	Number	6	9	3	18
	%	33,3	50,0	16,7	100,0
Total		22	48	27	97
%		22,7	49,5	27,8	100,0

Chi-square: 4,064, significance value: 0,397
Note: no subcontracting linkages: with 0 firms; Low intensity of subcontracting linkages: with 1-9 firms; High intensity of subcontracting linkages: with 9+ firms. Firms with low R&D expenditure rate: 0-25%; Firms with high R&D expenditure rate: 26-99%.

Table 6 shows the relation between subcontracting network and R&D personnel in Ankara defense and aviation cluster. Similar to R&D expenditures, there is no statistically significant differentiation between subcontracting networks and R&D personnel (Table 6). Firms both with no master’s and doctoral graduate personnel and firms with high master and doctorate graduate personnel ratio have frequent subcontracting relationships.

Table 6. *Subcontracting network and master and doctoral graduates in Ankara defense and aviation cluster*

The ratio of Master's and doctoral graduates to total employees		Intensity of subcontracting linkages			Total
		No	low	high	
None	number	10	22	12	44
	%	22,7%	50,0%	27,3%	100,0%
Low	Number	4	13	13	30
	%	13,3%	43,3%	43,3%	100,0%
High	Number	8	13	2	23
	%	34,8%	56,5%	8,7%	100,0%
Total			48	27	97
%			49,5%	27,8%	100,0%

Chi-square: 8.724; significance value: 0,068
No Master's and doctoral graduates: 0; Low Master's and doctoral graduates: 1-3; High Master's and doctoral graduates: 4+

According to the results, there is no relationship between subcontracting relations and R&D activities and the sector-specific contract relations have been established independently of the innovative capacity of networks in Ankara defense and aviation cluster.

5.2. The relationship between service network and R&D activities in Ankara defense and aviation cluster

Relationships between service network and R&D activities in Ankara defense and aviation cluster are analyzed with two R&D variables; regarding the relationship between R&D expenditure rate, and intensity of service networks, it is seen that there is a statistically significant relationship (Table 7). It can be said that, firms not located in service network have mostly no R&D expenditure also. Moreover, firms with high R&D expenditure have a large proportion of low intensity of service linkages (Tablo.7).

Table 7. *The service network and R&D expenditure in Ankara defense and aviation cluster*

The ratio of R&D expenditure in the total expenditure		Intensity of service Network			Total
		No	low	high	
None	number	12	21	10	43
	%	27,9%	48,8%	23,3%	100,0%
Low	Number	2	17	17	36
	%	5,6%	47,2%	47,2%	100,0%
High	Number	5	13	0	18
	%	27,8%	72,2%	0,0%	100,0%
Total			51	27	97
%			52,6%	27,8%	100,0%

Chi-square: 17.582, significance value: 0,001
Note: There is no Service linkages: with 0 firm; Low intensity of service linkages: with 1-11 firms; High intensity of service linkages: with 12+ firms.

The second variable used to measure R&D activities is the ratio of qualified R&D personnel (Table 8). It is observed that there is a statistically significant differentiation between the service networks and the proportion of masters and doctoral graduates to total employees.

Table 8. *The service network and master and doctoral graduates in Ankara defense and aviation cluster*

The proportion of Master's and doctoral graduates to total employees		Density of Service Network			Total
		No	low	high	
None	number	12	23	9	44
	%	27,3%	52,3%	20,5%	100,0%
Low	Number	1	15	14	30
	%	3,3%	50,0%	46,7%	100,0%
High	Number	6	13	4	23
	%	26,1%	56,5%	17,4%	100,0%
Total			51	27	97
%			52,6%	27,8%	100,0%

Chi-square: 11,560, significance value: 0,021

The relation between the subcontracting network and service network with R&D activities is statistically differentiated. While statistically significant differentiation between subcontracting network and R&D activities could not be determined, a relation between R&D activities and service could be observed. This shows that subcontracting networks in the sector have been established and been working independent of innovation capacity, but service network covering the R&D network are more frequent in innovative firms with high R&D activities.

6. CONCLUSION

The first research question of the article is related to spatial proximity concept in production networks, and enquiries whether space is reproduced in production networks or not. The results of the production network analysis carried out in Ankara defense and aviation cluster offers important clues in this argument.

The subcontracting network analysis indicates that two leading agglomerations in Ankara cluster are Ostim and İvedik OIZs, followed by Sincan 1st OIZ, Çankaya, Kazan and Başkent OIZs respectively. The sub-regions are located on the network map according to their linkages, despite their geographic location. The subcontracting network map brings a new dimension to the spatial proximity debate; as network centrality gains importance, real geographical position loses strength and 'organized proximity' is defined in the network in Ankara defense and aviation cluster. For example, it is seen that the Ostim and İvedik OIZs are at the same distance to Sincan 1st OIZ, Başkent OIZ and Kazan firms on the Ankara network map. Moreover, ASELSAN, with more frequent linkages with subcontractors compared to the other main contractors, is positioned in the center of subcontracting network map. The network analysis has shown that the subcontracting linkages of the technoparks are poor. Hence, they positioned accordingly on the subcontracting network map of Ankara and are not at a central position.

Firms' positions are changing and are redefined consistently with service linkages on the service network map of Ankara. In service network, Çankaya can be seen as a service delivery center. Ostim and İvedik OIZs are sub-regions where service demand is concentrated. In the service network map METU Technopark has a central position. Hence, similar to the subcontracting network map, it is seen that the real geographical position and network position of firms differ in Ankara service network map.

In the paper, R&D is discussed under two headings; R&D agreements/projects and R&D support. The network analysis of R&D agreements/projects in Ankara shows that subcontractors have established significant R&D relationship and partnership with the main contractor firms. In other words, the basic steering leaders of innovation and technology in the sector are the main contractor firms. Another important result is that TÜBİTAK has a key position in R&D agreements. TÜBİTAK has also a central position at R&D support, and the following two institutions are KOSGEB and SSM. However, the relationships with the universities are limited as also evident in other sectors in Turkey.

Comparative evaluation of the network maps of Ankara defense and aviation cluster shows that the spatial proximity concept has insufficient explanatory power in cluster studies. In Ankara, the number of linkages of subcontracting network is high and OIZs take place at a centralized position. Service networks include less linkage compared to subcontracting networks and technoparks are located at a more central position, compared to OIZs. R&D agreements/projects network offers a less dense network map with fewer links. In this network map, main contractors are in the center, which reflects the R&D structure of the sector in Ankara; the main contractors are responsible for the technology production and technology dissemination among the subcontractors. In the R&D support networks, a non-intensive network structure is monitored and public institutions take central position. As a conclusion of Ankara network maps in the firm's network position two critical issues are gaining importance; the first is how central they are in the network, and the other is their intensity in linkages to the other nodes in the network. Firms are located in many different networks at the same time, and accordingly, their locations on the networks differentiate in each type of network and also differentiate from their geographical position.

The second research question of the article focuses on the relationship between production networks and R&D activities. While statistically significant differentiation cannot be determined between subcontracting network and R&D activities, a relationship between service network and R&D activities is observed. Because the structure of subcontracting works does not contain the advanced technology in Ankara defense and aviation cluster, the relationship between subcontracting network and R&D activities is also expected to be weak. On the other hand, as service network comprise R&D-oriented information, technology and support linkages, service network and R&D activities are mutually supporting each other. In addition to supporting R&D activities, this result shows that policies supporting service network in the sector may also increase R&D activities.

Among other findings that may be a policy directing conclusion; it can be said that although R&D is influential in the innovation process of the industry, the R&D activities are limited especially among the subcontractors, and the main contractors are the pioneers for the subcontractors. Moreover, institutional support is evident in R&D operations, and in this context it is clear that the institutions that provide R&D support in the Ankara defense and aviation cluster are of great importance to subcontracting firms. And the universities do not stand out as important guides in the innovation process in Ankara.

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CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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