Investigation of European Union Horizon 2020 Information and Communication Technology Projects with the Social Network Analysis Method

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ABSTRACT

This study aims to examine the partnerships of the projects accepted in the Horizon 2020 grant support program, which supports innovative Research and Development (R&D) projects of the European Union, using social network analysis according to criteria such as participant countries, the project subjects in which they participate, and the number of funds they receive. Social network analysis can be used in many different areas, as well as in the analysis of collaborations and partnerships. Turkey's partnership has not been examined in detail for such international multi-partner collaborations. While taking advantage of the opportunity to follow the trend of technology by conducting innovative R&D studies with leading organizations in many different strategic fields, the interest and participation rate of Turkey is increasing day by day in such programs, offering opportunities to obtain grant incentives. Examining the network of collaborations established so far in this field can provide various inferences and suggestions for strategic partnerships.

Keywords-social network analysis; international collaboration; Horizon 2020

I. INTRODUCTION

All institutions that are aware of the impact of international cooperation in the field of science and technology give priority to strategic partnerships [1]. Social Network Analysis (SNA) is used in many fields. Although there are studies that investigate the projects and partnerships accepted in the EU Horizon 2020 program, which is the subject of this study, no studies on Turkey's performance and cooperation have been found for this program. This study aimed to fill this gap in the literature and reveal what kind of cooperation should be prioritized for Turkey to be more effective in such programs. To observe the areas where countries are active, 1276 ICT projects are classified into 20 different topics. The success of the countries in coordinating calls was calculated using weighting analysis and examined whether the calculated country achievement scores related to the degree of centrality. Finally, the types of institutions of central countries and Turkey were examined, revealing the types of Turkish institutions that should be more active in such programs. Studies have been carried out in many different fields, such as education, health, software, international and interinstitutional relations, etc., using SNA.

Authors in [2] aimed to understand how the accuracy of centralization behaves according to various amounts of error in the dataset, investigating a large number of sample networks by adding a controlled amount of error. The results showed that accuracy decreases as the amount of error increases. In [3], a study was conducted in the software industry using SNA, focusing on topics such as monitoring architectural changes, examining the effects of elements, and developing automated tools for architectural analysis. In [4], SNA was applied to obtain design principles to form a clinical team, based on the interactions that are important to increase information flow and achieve the intended results. In [5], SNA was used to explore patterns of collaboration and seek advice between schools, showing that while school networks are interconnected, overall interschool collaboration and advice-seeking activities are at low levels. In [6], a study was conducted on Clean Development Mechanism (CDM) projects, suggesting that the status of a country on the network is a sign of its strength in the entire network. The results showed that the participating organizations could decide which countries are more attractive to invest in the CDM market. In [8], successful projects and their partnerships in EUREKA were investigated using SNA, aiming to map successful projects of Central and Southeast European countries and identify the best-performing countries between 2002 and 2009, publishing a report on the results of participation in the 7th Framework Program (FP7). According to the findings, 86% of the collaborations in the 6th Framework Program (FP6) were not renewed in FP7, and universities and research organizations "provided an advantage because they were centrally located in the joint participation network of the framework programs" [9]. In [10], SNA was used to examine the international collaborations of the countries participating in the Horizon 2020 program, showing that countries with a high degree of centrality obtained large funding. This study also showed that high centrality (degree, closeness, and betweenness) is not an indicator of success rate. In [11], the capabilities of the Italy/Calabria region were mapped with SNA, demonstrating that its capacity in issues such as climate action, food and agriculture, and information and communication technologies is strong.

II. SOCIAL NETWORK ANALYSIS

A social network is a social structure consisting of individuals or organizations connected by one or more specific types of dependency, such as friendship, kinship, mutual interest, financial exchange, etc. [12]. SNA aims to explore social structures using networks and graph theory. Connected structures are characterized by nodes, which are individual actors, people, or things within the network. In addition, the ties that bind them are characterized by edges or links (relationships or interactions). The ability of SNA to be used in a wide variety of domains is due to the flexibility of the nodes and ties. Although primarily involving relations between people, ties between groups or organizations and relations between nation-states or international alliances can also be examined with SNA [7]. The purpose of SNA is not only to map and measure the relationships between nodes, but also to understand the structure of a network, draw conclusions about the impact of the relationship on an actor, and understand the defining characteristics, structures, and consequences of the relationships between them [13]. Examples of social structures commonly visualized with SNA are social media networks, information circulation networks, friendship networks, business networks, working relationships, collaborations, kinship, and disease transmission. In these networks, nodes are usually visualized as points, and ties are visualized as lines [14].

A. Social Network Analysis Metrics

Using many different metrics in the SNA, inferences can be made about the location and status of each individual in the network, the status of the most important actors, and the general characteristic structure of the network. In this context, the centrality criterion and its breakdown within itself are evaluated as node-based criteria in the graph structure. Apart from this, criteria such as cluster coefficient, cliques, diameter, density, etc., provide information about the general characteristic features of the graph. The centrality metric seeks answers to the questions of which actor is the most important on the graph and is the most common and effective metric to determine its importance. The centrality metric is expressed in three dimensions: the ability of an actor to communicate with others, his ability to control others, and his closeness to others [15]. According to these approaches, the centrality metric is examined under different sub-metrics, each showing different information about the node. This section examines the degree centrality, the closeness centrality, the betweenness centrality, and the eigenvector centrality. The number of links a node has with other actors in the network means the number of lines related to what is called Degree Centrality [8]. Actors with a high degree centrality are the most visible actors and have more direct contact with other actors on the network [16]. Although degree centrality is expressed as the number of edges connected to the node in undirected networks, it is handled as internal and external degrees in directed networks. The number of incoming connections to the relevant node represents the internal degree, the number of outgoing connections represents the external degree, and the node degree is the sum of these two values. In social networks, this metric is based on the principle that the actor with the most connections in real life is the most important. In other words, if the node has a higher degree centrality, it has more importance in the network. In directional networks, internal degree centrality represents the popularity of an individual in the social network, and external degree centrality represents the individual's sociability [17].

Closeness centrality refers to how close an actor is to the other actors in the network. The main idea is that an actor's ability to interact quickly with others depends on its central location [16]. This metric can be used to identify the actors in the best position that can affect the entire network most quickly. When calculating the closeness centrality of a node, the average of the shortest path lengths of that node to all other nodes in the network is calculated, and the inverse of the obtained value is taken. Betweenness centrality indicates which nodes are more likely to be in communication paths between other nodes. In other words, betweenness centrality is not concerned with the proximity of a node to other nodes, but with its location on the shortest path between other nodes [17]. When calculating betweenness centrality, first it should be found how many shortest paths exist between a pair of nodes (x, y), then count how many of the shortest paths between these two nodes contain the v node, and a ratio is obtained by dividing these two numbers. After this process is calculated for all pairs of nodes, the sum of the calculated ratios is found as the betweenness centrality of node v.

Eigenvector centrality is related to a node's connections with other nodes of high importance. A node with many connections does not need to have high eigenvector centrality, and a node with high eigenvector centrality does not necessarily need to have many connections. This approach is related to the ability to make many friends in high places in real-life networks [17]. A node's eigenvector centrality is affected by the importance and weight of other nodes to which it is connected. Eigenvector centrality depends on both the quality and the number of connections. If a node has few but high-quality connections, its eigenvector centrality may be greater than a node with many but average-quality connections [18]. To define the diameter of a graph, it is necessary to first define the shortest path, which is the minimum number of links required to connect two nodes in the network. The diameter of a graph is defined as the longest of the shortest paths between nodes in the network and is one of the key SNA metrics that gives information on the size of the network in general [17].

Density is obtained by dividing the total number of connections an actor has by the total number of possible connections that he can have. A high result indicates that the network is dense. Dense networks are likely to be found in small and stable communities with few outside contacts and a high degree of social interaction. On the contrary, loose social networks tend to thrive in larger, unstable communities that have many external contacts and exhibit a relative lack of social cohesion [19]. Density values can take values between [0, 1]. Density will approach 1 if there is a strong relationship between the nodes of the graph and 0 if there is a weak relationship. It is a useful metric used to make comparisons and inferences. The clustering coefficient is a measure of the probability that two partners of a node will be partners. The basis of this metric is the concept of transitivity. It is considered that there is a high probability of a relationship between the x and z nodes in a graph if there is a relationship between the x and y and a relationship between the y and z nodes. A complete graph is formed when all nodes are related to each other [18].

III. HORIZON 2020

Horizon 2020, is the European Union's research and innovation grant support program that operated between 2014 and 2020. The main purpose of the program, with a total budget of 80 billion euros, was to strengthen Europe in all areas by encouraging technology development and multi-international cooperation. This program aimed to enable Europe to produce world-class science, eliminate barriers to innovation, and facilitate the public and private sectors to work together to deliver innovation [22]. Different types of legal entities participated in Horizon 2020, such as universities, Small and Medium Enterprises (SMEs), large companies, research institutions, and Non-Governmental Organizations (NGOs). The biannual work programs at Horizon 2020 included funding opportunities and calls. The minimum number of participants and the requirements for the projects varied according to the type of project. The main condition sought in all applications to the Framework Programs, except for individual projects, is cooperation. In general, at least three independent organizations from at least three different EU member states or associated countries should take part as partners in Horizon 2020 projects.

Turkey participated in this program since the EU 6th Framework Program. The EU 6th Framework Program took place between 2002 and 2006, was replaced by the EU 7th Framework Program covering the years 2007-2013, continued from 2014 to 2020 as the Horizon 2020 program, and was followed by the Horizon Europe program that covers the years 2021-2027. Turkey's representative TÜBİTAK transferred 451 million euros to this program, as each country participates by giving a contribution. Therefore, organizations in Turkey were allowed to apply for this fund program. Each country aims to receive at least the amount of contribution it gives as a result of the international cooperation it establishes [24]. Today, technology development has proven to be very important in the analysis and processing of the volume of scientific information produced [25]. Horizon 2020 aimed to drive Europe's economic growth by combining research with innovation, focusing on three key pillars of scientific excellence, industrial leadership and competitiveness, and societal challenges. This study focused on the field of ICT, located in the facilitator and industrial technologies section, under industrial leadership [23]. European Commission appoints independent experts who evaluate project proposals and project operations and monitor program and policy processes [24]. Projects with evaluation scores above a threshold are ranked. Projects with higher scores are entitled to be funded if they do not exceed the budget allocated for the applied call. The Community Research and Development Information Service (CORDIS) [27] is the main source of results for projects funded by the European Commission's framework programs for research and innovation. CORDIS has a rich and structured public repository containing all project information from the European Commission, such as project fact sheets, participants, reports, outputs, and links to open-access publications. CORDIS has published a dataset on the European Union Open Data portal, including information on projects and participants funded by the EU under the Horizon 2020 framework.

IV. METHODS AND APPLICATION

A. Data and Visualization

This study used data from CORDIS. Datasets are updated monthly on the CORDIS portal, and all projects accepted in the Horizon 2020 program are publicly published. This study analyzed data from 1276 projects with a total of 11384 partnerships. The dataset for each participant is listed with its CORDIS registration number (RCN), project ID, project abbreviation, the role of the organization in the project (participant or coordinator), the name of the organization, the type of organization, the grant amount given by the European Commission (in EUR), and the country in which the organization is located. Figure 1 shows a network where the countries with the highest degree-centricity (with the most diverse partnerships in all ICT projects) are positioned to be the most centrally located and have the largest symbols.

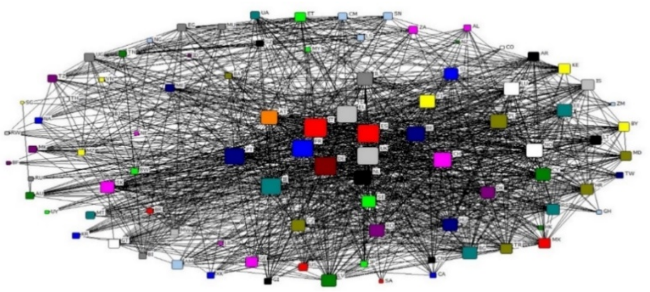

Fig. 1. Network image of Horizon 2020 ICT projects created by 92 countries.

This study selected a total of 31 countries, including EU countries, England, Switzerland, Norway, and Turkey, which are the main participants of the Horizon 2020 program, to make a more specific analysis. In this context, when the network analysis graph was drawn again, a clearer visual was obtained, as shown in Figure 2. The countries in the most central positions are Italy, Germany, England, Spain, Greece, and France. This image also highlights the strength of the bonds, showing the countries that have the strongest ties to the central actors, which are Belgium, Switzerland, the Netherlands, and Austria.

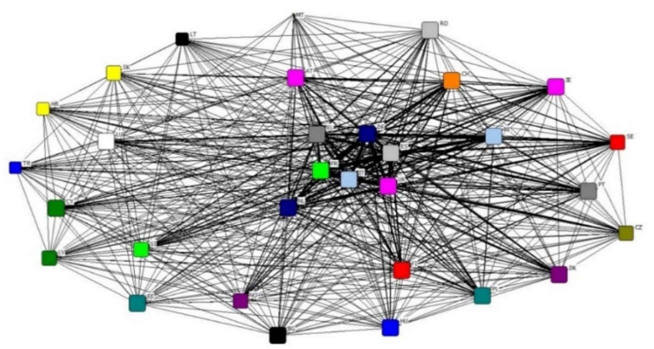

Fig. 2. Network image created with 31 countries in Horizon2020 ICT projects.

B. *General Features of the Network*

Table I shows the number of nodes, the number of links, the density degree, the average distance, and the diameter values of the undirected network consisting of 31 countries.

TABLE I. NETWORK FEATURES

Feature	Value
Nodes	31
Ties	908
Density	0.976
Average distance	1.024
Diameter	2

There are 31 actors and 908 ties in the network. The density of the mesh was found to be 0.976. Since this value is very close to 1, it can be said that this network has a high density and the actors are connected by strong ties. Diameter, another basic metric that gives information about the size of the mesh, took the value 2. So, the longest of the shortest paths in the node is at a distance of 2. Furthermore, the average distance between two actors was 1.024. As a result, it can be thought that the network is not very large, but it can be said that the density of the network is very high and therefore the actors are positioned very close to each other.

C. *Analysis of Social Network Analysis*

The positions of the countries were examined by performing SNA centrality metrics and clustering coefficient. Centrality values were calculated to examine the positions of the actors in the network. Table II shows the values of the countries in degree, betweenness, closeness, and eigenvector centrality, and their rankings according to these values. In Figure 3, the trend lines increase linearly according to degree centrality. Since the ranking of degree centrality and closeness centrality are the same, the two lines appear as a single line of green color. Around this linear line, the line highlighted in red indicates the betweenness centrality, and the line highlighted in dark blue indicates the eigenvector centrality ranking.

TABLE II. RANKING OF COUNTRIES BY DEGREE OF CENTRALITY

Degrees		Betweeness		Closeness		Eigenvector	
IT	72	IE	366.295	IT	0.0091	IT	0.181
DE	70	IT	284.502	DE	0.0089	UK	0.181
UK	69	DE	271.051	UK	0.0088	ES	0.179
ES	67	UK	223.356	ES	0.0087	EL	0.179
FR	66	FR	193.535	FR	0.0086	DE	0.175
EL	66	ES	187.545	EL	0.0086	FR	0.175
PT	62	AT	175.547	PT	0.0083	PT	0.171
IE	60	EL	160.905	IE	0.0082	BE	0.167
BE	56	PT	157.637	BE	0.0079	NO	0.163
CH	55	CH	94.77	CH	0.0079	PL	0.163
NL	55	NL	78.423	NL	0.0079	CH	0.162
NO	53	BE	77.43	NO	0.0078	NL	0.159
AT	51	NO	67.887	AT	0.0076	AT	0.158
PL	51	LU	61.306	PL	0.0076	FI	0.157
FI	49	FI	36.588	LU	0.0075	IE	0.156
LU	49	PL	30.391	FI	0.0075	HU	0.155
BG	46	BG	28.532	BG	0.0074	RO	0.154
CZ	42	CY	12.027	CZ	0.0071	CZ	0.147
SE	41	RO	11.719	DK	0.0071	SI	0.144
DK	41	SE	11.126	SE	0.0071	HR	0.142
SI	40	SK	10.411	SK	0.0070	SE	0.14
SK	40	CZ	9.471	SI	0.0070	SK	0.138
HR	39	SI	4.273	HR	0.0070	DK	0.136
TR	35	HR	3.82	TR	0.0068	TR	0.122
LT	30	LT	0	LT	0.0066	LT	0.117
MT	23	MT	0	MT	0.0063	MT	0.092

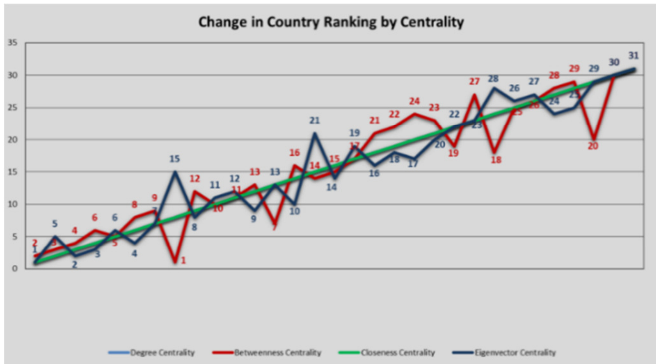

Fig. 3. Representation of country rank change by centrality metrics.

As can be seen in Table IV and Figure 3, when looking at the country rankings according to their degree centrality, Italy developed the most cooperation by establishing connections with 72 out of 92 partners in ICT projects, while Germany, England, Spain, and Greece followed. On the other hand, Turkey established partnerships with 35 different countries and ranked 29th.

Ireland, Italy, Germany, England, and France are the countries with the highest values of betweeness centrality. Ireland ranked 8th in degree centrality and 1st in betweenness centrality. This shows that Ireland is an effective actor with the ability to control the flow of information in the network. In addition, other countries that stand out in the chart and jumped into betweenness centrality are Austria, Sweden, and Turkey. Turkey has risen to the 20th place in betweenness centrality. This shows that Turkey's ability to cooperate with a wide range of actors is less than its capacity to influence the flow of information in the network by taking the shortest paths. As stated earlier, closeness centrality is related to the sum of the shortest path lengths of an actor to other actors in the network. Turkey was ranked 29th. When the eigenvector centrality is examined, Italy, England, Spain, Greece, and Germany are seen as the actors with the higher values. This metric, since the importance of the actors with whom the actors are connected is included, shows that these countries have a high degree of relationship with the important actors. Although Norway and Poland have lower rankings in other metrics, they are among the top 10 countries in the eigenvector centrality ranking. This shows that Norway and Poland are partnering with strong partners, even if they do not establish more partnership relations than the more centralized countries in the network. In addition to that, Ireland and Finland showed a dramatic decrease in this ranking, which was one of the most striking changes in the chart. Turkey is seen to be in the 29th place in this ranking. To examine the positions of the actors in the network, the centrality values were calculated first. Table III shows the values of the countries in degree centrality and their ranking.

TABLE III. RANKING OF COUNTRIES BY DEGREE CENTRALITY

Country	Clustering coefficient	nPairs	Number of neighborhoods
DE	40.28	435	30
ES	42.06	435	30
IT	42.86	435	30
FR	43.00	435	30
UK	43.24	435	30
EL	44.89	435	30
NL	46.19	435	30
BE	46.29	435	30
CH	47.42	435	30
PL	47.89	435	30
IE	48.26	435	30
FI	48.27	435	30
PT	48.41	435	30
AT	49.19	435	30
DK	49.66	435	30
EE	50.03	435	30
CY	50.08	435	30
LU	50.15	435	30
BG	50.36	435	30
RO	50.70	435	30
HU	50.71	435	30
SE	51.96	406	29
NO	53.29	406	29
SI	53.33	406	29
CZ	53.47	406	29
SK	54.39	406	29
LV	54.41	406	29
LT	57.85	378	28
HR	57.87	378	28
TR	61.70	351	27
MT	85.77	210	21

The second column, "nPairs", represents the number of all possible pairs of actors in the neighborhood formed by the neighbors with whom the actor is in contact or, in other words, all possible connections. Neighbor numbers are given in the fourth column. When the clustering coefficient of each actor is ranked from the smallest to the largest, it is seen that Germany's neighbors are connected with the least intensity, followed by Spain, Italy, France, England, and Greece. In addition, Malta, Turkey, Croatia, and Lithuania were last on the list, and their neighbors also bonded highly. The fact that the actors with low clustering density are those with a high degree of centrality indicates that these actors are the most active in the network and their clustering densities are low because their neighbors are not as active as themselves. On average, actors with higher rankings have been reported to have lower clustering coefficients on average [26].

D. *Partnerships of Turkey*

Table IV shows the countries with which Turkey cooperates the most. Turkey has realized the higher cooperation with countries with the highest degree centrality. This may be a natural consequence of those countries' maximum number of partnerships in this program.

TABLE IV. TURKEY'S TOP TEN PARTNERSHIPS

Country	Number of partners	Country	Number of partners
ES	99	EL	38
DE	67	PT	27
IT	54	NL	24
FR	47	BE	23
UK	43	AT	21

Increasing the number of collaborations with Ireland, which has the highest degree of betweenness centrality and, as a result, the ability to affect the information flow at the highest level, can enable Turkey to achieve greater success in this field. In addition, increasing cooperation with countries with high eigenvector degrees can enable Turkey to meet successful partners in important positions. Norway and Poland, which are not included in Table IV but have achieved a slight jump in eigenvector centrality, are actors that can be considered in this regard. Furthermore, as a result of the examination made using clique analysis, Switzerland was found to be the ninth country participating in the clustering and showed closeness to the most central partners. Considering the current situation of Turkey, increasing its ties with Switzerland may allow it to be more included and positively affect its performance.

E. *Partnerships of Turkey*

The acceptance rates of all ICT calls were calculated by dividing the number of projects accepted within its scope by the total number of applications, and then inversely, the importance of that call was obtained. The coordinator partner is responsible for establishing and coordinating the project consortium. Additionally, the coordinator has the largest role in writing a good project proposal. For this reason, during the calculation of the success rates of countries by weight analysis, the number of times the countries participated as coordinators was considered.

ICT calls are classified under 20 different headings according to subject areas and the calculated country success scores were distributed according to the classification made under these headings. In the weighting analysis management, the Acceptance Rate of ICT-x Call (CAR) was calculated first by:

$$AR_x = \frac{NNA_x}{TNA_x} \quad (1)$$

where NNA_x is the number of applications accepted in the opened ICT-x call, TNA_x is the total number of applications in the opened ICT-x call. The *k*-th country's coordinator achievement score is given by:

$$CCAS_x = \sum_{x=1}^{20} \frac{NCC_{kx}}{AR_x} \quad k = 1,2,\ldots,31 \quad (2)$$

where NCC_{kx} is the number of coordinator ships from the *k*-th country on the *x*-th call. As can be seen in Table V, the top 5 most successful countries according to the total success score are Spain, England, Germany, Italy, and France, while Turkey ranks 24th in this list. This situation shows that Turkey does not take an active role as a coordinator in the program. Although Germany and Spain seem to be the partners with the highest scores on an equal number of topics, Spain's high success, especially in the "Horizontal ICT innovation action", made it the first in the ranking of the most successful countries in total scoring. When examining the countries with which Turkey has cooperated the most, it is seen that there is a strong amount of cooperation with the first six most successful countries according to the weight analysis. However, Finland, the seventh most successful country, is not among the top ten countries with which Turkey has developed a great deal of cooperation. For this reason, further cooperation between Finland and Turkey may be an important step in obtaining successful project applications.

TABLE V. ACHIEVEMENT SCORES ACCORDING TO THE WEIGHTING ANALYSIS OF COUNTRIES

	5G	A new generation of components and systems	Advanced computing and cloud computing	AI and digitising European industry and economy	Content technologies and information management	Cross-cutting activities	Cybersecurity	European data infrastructure: HPC, big data and cloud technologies	Horizontal ICT innovation action	ICT cross-cutting activities	ICT key enabling technologies	Innovation and entrepreneurship support	International cooperation actions	Micro- and nano- electronic technologies, photonics	Next generation internet (NGI)	Platforms and pilots	Responsibility and creativity	Robotics and autonomous systems	Support actions	Support to hubs	Total success
ES	33	14	36	87	335	0	23	65	1193	36	18	15	6	43	264	28	2	87	0	10	2295
UK	0	21	18	20	261	8	0	9	805	6	11	0	9	12	190	0	5	80	14	0	1469
DE	40	124	37	n	202	8	21	51	305	44	16	10	9	63	170	12	0	82	0	8	1202
IT	22	42	27	63	136	20	31	37	404	42	22	7	30	18	184	12	0	148	0	5	1250
FR	8	100	31	108	49	8	12	5	540	6	25	12	3	39	79	6	7	65	0	9	1112
EL	23	23	22	79	189	13	13	93	128	21	14	7	11	22	188	0	0	23	0	2	871
FI	8	4	0	29	45	4	0	0	306	15	12	3	0	7	35	5	0	19	0	6	498
AT	0	36	0	31	60	13	3	25	169	12	20	0	3	11	71	0	7	31	0	0	492
NL	3	10	0	40	102	0	6	9	141	6	24	0	11	30	41	0	0	40	0	10	473
BE	3	32	22	34	74	8	4	0	23	12	14	0	0	32	88	0	7	20	0	2	375
IE	0	21	5	9	73	0	0	19	99	0	4	0	21	0	86	7	2	0	9	0	355
PT	3	4	0	14	8	13	15	13	152	0	0	0	9	0	74	8	0	0	0	2	315
SE	3	10	0	35	26	0	0	0	148	0	0	0	9	3	25	0	0	48	0	0	307
DK	0	10	0	5	8	0	8	0	163	0	0	0	0	6	25	0	5	27	9	2	268
NO	5	10	9	13	26	0	0	13	130	24	7	0	9	0	11	0	5	0	0	3	265
PL	0	0	5	0	20	8	0	0	178	0	0	0	0	0	8	0	0	6	0	3	228
HU	0	0	0	0	0	0	8	0	153	0	0	7	0	0	15	0	0	0	0	0	183
EE	3	10	0	0	0	0	0	0	143	0	0	7	0	0	3	0	0	0	0	0	166
CH	0	15	0	8	14	12	0	35	5	0	0	0	7	0	38	0	0	9	0	3	146
SI	0	0	0	9	0	0	0	9	99	0	0	0	0	0	12	0	0	11	0	0	140
CZ	0	0	0	0	8	0	0	5	41	0	0	0	0	0	5	0	0	0	0	0	59
LU	0	0	0	0	0	0	0	0	41	0	0	0	0	2	8	0	0	0	0	0	51
TR	0	0	0	0	0	0	0	0	41	0	0	0	0	0	0	0	0	0	0	0	41
CY	0	0	0	0	0	0	0	0	23	0	4	0	0	0	0	0	0	9	0	0	36
LT	0	0	0	7	0	0	0	0	18	0	0	7	0	0	0	0	0	0	0	2	34
SK	0	0	0	0	0	0	0	0	23	0	0	0	0	0	8	0	0	0	0	0	31
RS	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	15
RO	0	0	0	0	5	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	14
BG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5

F. Comparison of Country Achievement Scores with SNA Metrics and Country Success Percentage

The relationship between country achievement scores, degree centrality, and country success percentages was examined. The success percentage of the countries, which is the ratio obtained from the total number of project applications made in the Horizon 2020 ICT field and the number of accepted project applications, was taken from the EU Horizon 2020 indicator panel [26]. Table VI shows the degree centrality, success percentages, and success scores of the countries.

TABLE VI. DEGREE CENTRALITIES, SUCCESS RATES, AND SUCCESS SCORES PER COUNTRY

Country	Degree centrality	Success rates	Success scores
CH	55	17.90%	144
CZ	42	17.42%	59
BE	56	16.17%	374
AT	51	15.65%	492
FR	66	15.38%	1114
NO	53	15.25%	264
FI	49	15.21%	51
NL	55	15.21%	474
DK	41	14.81%	308
DE	70	14.68%	1280
IE	60	14.65%	354
LT	30	14.07%	35
LU	49	13.61%	498
EL	66	13.43%	873
SE	41	13.16%	268
UK	69	12.86%	1469
PL	51	12.73%	226
SI	40	12.32%	31
CY	44	12.06%	36
ES	67	12.02%	2293
PT	62	11.92%	316
SK	40	11.68%	140
IT	72	11.51%	1251
HU	46	10.93%	183
EE	45	10.66%	167
RO	45	10.40%	14
TR	35	7.85%	41
BG	46	6.61%	5
CH	55	17.90%	144
CZ	42	17.42%	59
BE	56	16.17%	374

Correlation analysis provides information on the direction and power of the relationship between two variables. A correlation analysis was conducted to examine the relationship between degree centrality, success percentages, and achievement scores of the countries. To understand whether there is a relationship between the variables, the following hypotheses were established:

H_0: There is no relationship between the two variables

H_1: There is a relationship between two variables

To determine the result of the hypothesis test, the correlation Table and the P-value were examined, and Figure 4 shows the results.

Pairwise Pearson Correlations

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
Success Scores	Success Rates	28	0.080	(-0.302, 0.440)	0.686
Degree Centrality	Success Rates	28	0.211	(-0.176, 0.541)	0.282
Degree Centrality	Success Scores	28	0.788	(0.588, 0.897)	0.000

Fig. 4. Country's degree centrality, success rates, and success scores

In the correlation analysis, if the P-value is less than 0.05, the H_0 hypothesis is rejected and the H_1 hypothesis is accepted. As can be seen in the figure above, there is a relationship between degree centrality and country success scores. However, the country's success percentage is not related to its achievement score and degree centrality.

Italy, Germany, England, Spain, and France were the top five countries in terms of degree centrality and country success scores, while Switzerland, Czech Republic, Belgium, Austria, and France are the most successful countries in country success percentages. The reason the country's success percentages have such a different ranking is that these countries have a good acceptance rate even if they are not as active as the most centralized countries in the ICT program. France, which is among the top five countries in both comparisons, has achieved both high cooperation and a good coordinator experience, although it has made far fewer applications than other central countries.

G. Comparison of The Types of Institutions Receiving the Funds by Country

Table VIII compares the types of the most successful organizations in Germany, England, France, Spain, and Italy, which are the most central countries, and Turkey.

TABLE VII. COMPARISON OF THE MOST SUCCESSFUL ORGANIZATION PERCENTAGE

Country	University	Private sector	Research institute	Public institution
Turkey	10%	80%	10%	0%
Italy	40%	30%	40%	0%
Germany	30%	50%	20%	0%
England	50%	30%	10%	10%
Spain	40%	20%	40%	0%
France	20%	50%	30%	0%

As can be seen in Table VII, research institutes and universities, as well as the private sector, are actively involved among the institutions that receive the highest funding in the most central countries. This situation can offer important clues about the issues Turkey needs to improve itself. Although only 10% universities and 10% research institutions are on the list of the most successful in Turkey, most of them are private sector institutions. In the most centralized countries, the sum of universities and research institutions makes up half and even more than half of the list. Universities and research institutes, which mostly carry out studies at the stage of basic research and the creation of new knowledge in a technology field, take an important role in the first steps of new knowledge and discovery and become an actor that directs the course of technology.

V. CONCLUSION AND RECOMMENDATIONS

SNA can be used in many different sectors and fields and is considered one of the powerful methods in examining collaboration and partnership relations. Conducting a network analysis provides a holistic view of the position of the partners in the network and information about the relations between them. This study used SNA to examine the projects that were accepted in the field of ICT in the Horizon 2020 program. The results showed that Italy, Germany, England, Spain, and France were the countries with the highest degree and closeness centralities. Ireland ranked first in betweenness centrality. The fact that Ireland achieved a high value in betweenness centrality shows that the country is an important factor that can control the flow of information. However, Ireland is not on Turkey's top partnership country list. Therefore, increasing cooperation with Ireland may improve Turkey's position. In addition, new collaborations can be developed with other potential partners in important places by establishing cooperation with Norway and Poland, which have rising rankings in eigenvector centrality. In addition, clustering coefficient and clique analysis were performed, and the percentages of actors' neighbors being neighbors to each other and which actors were closer to each other were examined. As a result, it was seen that the clustering coefficients of the countries could be low if they have high degree centrality. This situation is related to the fact that the neighbors of the central countries are not as active as themselves and do not establish much connection. The clique analysis showed that the central countries, with Spain and Germany in the first place, achieved the first merger by showing closeness. Switzerland, which is not on Turkey's top ten partnership countries list, was seen to establish close relations with the central countries by being included in the grouping in the 9th place. Turkey was found in the 25th place and was characterized as an isolated actor. Turkey can consider Switzerland as another country that should increase its cooperation. Another country that stands out is Sweden. Although Sweden has a low rank in degree centrality, its rise of ten places in the clique analysis shows that it also has strong relations with central European countries. These results show, with exceptions, that geographical closeness also affects collaboration.

In Horizon 2020 projects, it is an undeniable fact that the coordinator actor plays an essential role in the success of the project. The coordinator success of the countries was calculated under 20 different headings by weighting analysis. Spain, England, Germany, Italy, and France are the most successful countries, respectively. Whereas Turkey is seen to have developed high partnerships with the first six countries in the coordination success ranking, more cooperation with Finland, the seventh most successful country, can lead to successful projects. Degree centrality, country success scores, and country success percentages were compared, showing that there is only a relationship between degree centrality and country achievement scores. France is the only country in first place in all three rankings, has established partnerships with a high number of different countries, has developed coordinator skills, and is almost as successful as the other central countries, even though it makes much fewer applications.

Finally, the most centralized countries and Turkey's most-funded institution types were compared, showing that universities and research institutions in other countries have much more active participation than universities and research institutions in Turkey in Horizon 2020 ICT projects and have an important role in the success of the country. Participants in Turkey are mostly private sector organizations. More active participation of universities and research institutions, which carry out basic research and play an important role in introducing new knowledge and technology, will increase Turkey's success in the program and will be an important step in becoming a technology developer country. In the future, this study can be diversified with different and more in-depth statistical analyses by focusing on different social network analysis metrics.

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