Ranking Terrorist Nodes of 26/11 Mumbai Attack using Analytical Hierarchy Process with Social Network Analysis

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***Abstract*—26/11 Mumbai attack is one of the major terrorist attack in India, executed on November 26, 2008. For analyzing such terrorist attacks, Social Network Analysis (SNA) is the most effective technique, recognized worldwide. Various centrality measures of SNA have capability to find the key players/leaders and obtain a rank ordering of nodes in such networks. But, most of the times, each of these individual measures result in identifying different key players and rank ordering. Analytical Hierarchy Process (AHP) can be combined with existing SNA measures in order to find the overall ranking of nodes based upon decision maker's subjective or objective judgements. In this paper, 26/11 Mumbai terrorist network is analyzed using AHP with existing SNA centrality measures as decision criteria, to discover the overall ranking of all 13 terrorists involved in the attack and to find the key players/leaders among them. Further, sensitivity analysis is discussed to deal with changes in subjective judgements. The experimental results show that when AHP is combined with SNA centrality measures, results in more promising ranking of nodes in terrorist networks than only centrality is considered.**

Keywords—Analytical Hierarchy Process (AHP); Social Network Analysis (SNA); centrality measures; 26/11 terrorist attack; finding key players; ranking terrorist nodes

I. INTRODUCTION

In recent years, India has been witnessed frequent terrorist attacks. On November 26, 2008, one of the major terrorist attack, known as 26/11 terror attack, was executed in Mumbai (India) by members of Lashkar-e-Taiba (LeT), a Pakistan based terrorist group. Ten terrorists equipped with advanced weaponry and three handlers in Pakistan, were involved in the attack and five major locations in Mumbai were targeted, causing nearly 260 casualties from ten different countries [2], [3]. The attack was well planned and handlers from Pakistan were in communication with these terrorists, during the attack.

Various high-ended methodologies have been evolved over time for analyzing terrorist groups and networks. Social Network Analysis (SNA) is one of the most effective and predictive analytical tool for studying various terrorist activities. Just after tragic 9/11 terrorist attack, research based on SNA in counter-terrorism became very popular. In counter-terrorism domain, particularly, centrality measures of SNA [5], [6], [7], have been frequently used for identifying the key players/leaders and ranking of terrorists based on various terrorist networks/activities.

The Analytical Hierarchy Process (AHP), first proposed by Satty [15], [16], is a multiple attribute decision making technique for investigating and organizing complex decisions. Based on some criteria (attributes), alternatives and subjective or objective measures, AHP helps in finding relative importance or ranking of alternatives. In many cases, AHP is used as an effective tool for finding key players/leaders and ranking of nodes in various social network studies with respect to several criteria (attributes).

In this paper, 26/11 terrorist network is analyzed using AHP in addition with existing SNA Centrality measures, in order to discover the ranking of all 13 terrorists involved in the attack and identifying the key players/leaders among them. Data used for 26/11 terrorist network is based on the work done by [1] and Government of India's report on Mumbai attack [2].

The rest of the paper is structured as follows: Section 2 of the paper briefs about the SNA and various centrality measures for identifying key players/leaders and related research done in the Counter-Terrorism domain. Section 3 discusses about AHP process, steps for finding ranking of alternatives and related studies using AHP with SNA in various decision problems, including its application in Counter-Terrorism. Section 4 presents research work done by us of analyzing 26/11 attack network and ranking the terrorist nodes using AHP as a tool, in addition with SNA Centrality measures. Finally, work is concluded and some suggestions for future research is provided in Section 5.

II. SNA AND AHP : RANKING NODES IN SOCIAL NETWORK

A. *Social Network Analysis (SNA)*

Social Network Analysis (SNA) is a graph and network theory based approach for studying social relationships in terms of nodes (individuals, organizations, events etc.) and ties between them (relationship i.e. friendship, kinship, conversation, money transection, co-workers etc.). Various SNA measures has been evolved for representing relations among individuals, identifying key players/leaders and subgroups and communities, finding topology, examining strong or weak ties and strength of network.

Many studies are the evidence of effective use of SNA in Counter-Terrorism applications. For example, Krebs's work on 9/11 Al-Qaeda terrorist network and using SNA Centrality measures for finding key players [8], study of SNA and multi-agent models for destabilizing covert terrorist networks by Carley [9], [10], study of Noordin Top's terrorist network and disruption of terrorist networks using SNA centrality measures by Everton [11], analysis of 26/11 terror network using SNA by Azad [1], SNA based studies on major terrorist groups operating in India by [12], [13], our previous survey article on Social Network Analysis for Counter-Terrorism [14] etc.

Terrorist organizations/groups can be represented using SNA, as individual terrorist members as nodes and relationship among them as edges. This graph/network is often represented as an adjacency matrix. SNA offers several measures for finding key players or central node within the network and ranking of nodes in the network, often grouped as Centrality measures. Numerous measures of Centrality like Degree, Betweenness, Closeness and Eigenvector has been proposed over time for the same [5], [6].

Degree centrality [5] of particular node is the number of direct links to other nodes. Higher value of Degree Centrality often considers the node as an active individual in the network. In terrorist network study, this helps in identifying the leader or the hub of the network.

Betweenness centrality [5] infers the nodes, which act as a broker between groups or communities in the network. In any network, it is calculated as the number of times the node lie between the shortest paths between any pair. In terrorist networks, nodes with higher betweenness values help in identifying potential brokers between two groups or communities, which reflects powerful and influencing nodes, containing maximum information.

Closeness centrality [5] is a mean length of all shortest paths from an individual node to all other nodes in the network. In terrorist networks, nodes with high closeness values are much closer to other nodes and can help in accessing the information in quicker manner.

Eigenvector centrality [6] a variation of Degree Centrality, is a measure of how much an individual is connected to other highly connected members of the network. It infers the relative importance of a node, in terms of influence, to other connected nodes in the network. In terrorist networks, nodes with high eigenvector centrality help in identifying most central nodes in the network, globally and tracking individuals, well connected to other well connected actors.

B. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP), proposed by Saaty [15], [16], [17], in 1977, is a multiple attribute decision making technique to organize and analyze complex decision problems, based on various criteria (attributes), alternatives and subjective judgements on them. AHP also facilitates the objective values of criteria and alternatives for decision making. AHP is applied in many decision problems, for example, choosing the best alternative from a given set, ranking a set of alternatives, prioritizing alternatives, conflict resolution, quality management, corporate planning, government policy development etc.

In many recent studies, AHP is found out to be an effective technique in addition with SNA, especially for identifying key players/leaders and ranking of nodes in various social networks. Fox and Everton used AHP as a tool to find the influence and ranking of nodes in the social network [18] and to identify key nodes in Noordin terrorist network in this study [19]. Fox [20] in another study, used AHP combined with TOPSIS for ranking terrorist nodes in network. Liebowitz [21] studied the integration of AHP with SNA for knowledge mapping in organization.

The steps of AHP for finding the key players and ranking of nodes in particular social network can be outlined as follows,

Step 1: Build the decision hierarchy for the decision problem by decomposing the problem into a hierarchy comprising the decision goal, alternatives for achieving it, and the criteria and sub-criteria for assessing these alternatives.

Step 2: Establish priorities among the criteria, sub-criteria and alternatives, either by using,

- Saaty's nine-point scale (in Table I) to make series of judgments based on pairwise comparisons of the elements, or
- Objective measures and values available for criteria, sub-criteria and alternatives.

TABLE I. Saaty's Nine Point Scale for Pairwise Comparisions

Intensity of Importance	Importance
1	Equal
3	Moderate
5	Strong
7	Very Strong
9	Extreme
2,4,6,8	Intermediate Values

It result in pairwise comparison matrix for criteria, sub-criteria and alternatives. For ensuring the consistency of judgements, this matrix must be stable according to consistency ratio (CR) defined by Saaty [15], [17]. The value of CR should be less than or equal to 0.1 for pairwise comparison matrix.

Step 3: Using eigenvector method to estimate the weights of each criteria and sub-criteria, which result in comparative ranking of criteria and sub-criteria.

Step 4: For m criteria and n alternatives, aggregate criteria weights (the $m \times 1$ matrix) with values of alternatives with respect to each criteria (the $n \times m$ matrix), using matrix multiplication, in order to determine the final ranking of each alternatives (the $n \times 1$ matrix).

III. ANALYZING 26/11 NETWORK USING SNA AND AHP

26/11 Mumbai attack is one of the major terrorist attack in India. As confirmed by various sources [2], [3], [4], ten terrorists were involved in attacking five prime locations of the city, while three handlers from Pakistan were controlling these attackers. The details of these attackers and their handlers are mentioned in Table II and Table III.

TABLE II. LeT Handlers who Operated from Pakistan (P)

S. No.	Handler's Names	Place of Operation
1.	Abu Kaahfa	Pakistan (P)
2.	Wassi	Pakistan (P)
3.	Zarar	Pakistan (P)

Based on the work done by Azad [1] and government of India's report, revealing intercepted phone calls [2], data for 26/11 network is gathered in the form of adjacency matrix and social network graph.

TABLE III. Attackers who Operated in Mumbai

S. No.	Attacker's Name	Place of Operation
1.	Hafiz Arshad	Leopold Café and Bar (LC)
2.	Javed	Taj Mahal Hotel (TMH)
3.	Abu Shoaib	Taj Mahal Hotel (TMH)
4.	Abu Umer	Leopold Café and Bar (LC)
5.	Abdul Rehman	Oberoi-Trident Hotel (OTH)
6.	Fahadullah	Oberoi-Trident Hotel (OTH)
7.	Baba Imran	Nariman House (NH)
8.	Nasir	Nariman House (NH)
9.	Ismail Khan	Chhatrapati Shivaji Terminus (CST)
10	Ajmal Amir Kasab	Chhatrapati Shivaji Terminus (CST)

Fig. 1 shows the adjacency matrix and Fig. 2 shows the social network graph for 26/11 network, produced using UCINET [22] and NodeXL [23].

	Abu	Wassi	Zarar	Hafiz	Javed	Abu	Abu	Abdul	Fahad	Baba	Nasir	Ismail	Ajmal
Abu Kaahfa		1	1	0	0	0	0	0	0	0	0	0	0
Wassi	1		1	1	0	0	1	0	0	1	1		
Zarar	1	1		0	0	0	0	0	0	0	0	0	0
Hafiz Arshad	0	1	0		1	1	1	0	0	0	0	0	0
Javed	0	0	0	1		0	1	0	0	0	0	0	0
Abu Shoaib				1	1		1	0	0	0	0	0	0
Abu Umer	0	1	0	1	1	1		0	0	0	0	0	0
Abdul Rehman	1								1				
Fahadullah	0	0	1	0	0	0	0	1		0	0	0	0
Baba Imran	0	1	0	0	0	0	0	0	0		0	0	0
Nasir	0	1	0	0	0	0	0	0	0	0		0	0
Ismail Khan	0	0	0	0	0	0	0	0	0	0	0		1
Ajmal Amir Kasab	0	0	0	0	0	0	0	0	0	0	0	1	

Fig. 1. Adjacency Matrix of 26/11 Network [1]

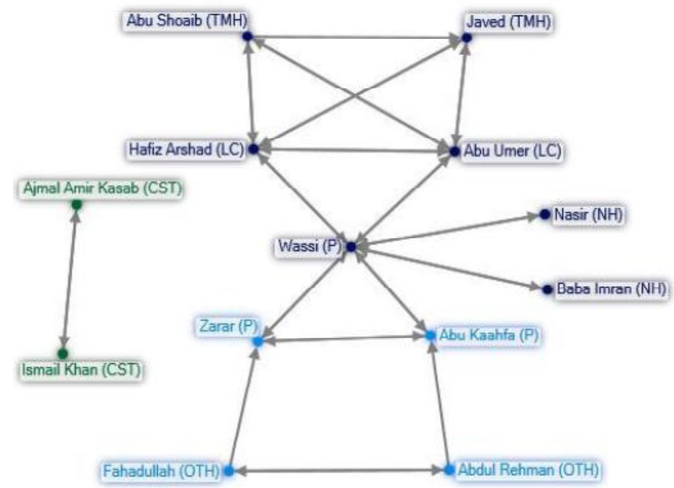

Fig. 2. Social Network Graph of 26/11 Network [1]

A. *Applying SNA on 26/11 network*

Now based on various SNA Centrality measures, for 26/11 network, value of six important centrality measures (Degree, Eigenvector, In-Degree, Out-Degree, Closeness and Betweenness) are calculated and verified with the help of UCINET [22], ORA [24] and Gephi [25]. All these centrality values are normalized between 0 and 1 for further use in AHP.

These normalized values and their distributions are shown in Table IV and Fig. 3 respectively.

TABLE IV. SNA Centrality Measure Values for 26/11 Network (Normalized)

Terrorist Name	Degree	Eigenvector	In-Degree	Out-Degree	Closeness	Betweenness
Abu Kaahfa	0.080645	0.081041	0.096774	0.064516	0.083074	0.078947
Wassi	0.193548	0.178492	0.193548	0.193548	0.051921	0.568421
Zarar	0.080645	0.081041	0.096774	0.064516	0.083074	0.078947
Hafiz Arshad	0.129032	0.163631	0.129032	0.129032	0.062305	0.131579
Javed	0.080645	0.122399	0.096774	0.064516	0.093458	0
Abu Shoaib	0.080645	0.09498	0.064516	0.096774	0.088266	0
Abu Umer	0.129032	0.163631	0.129032	0.129032	0.062305	0.131579
Abdul Rehman	0.048387	0.00198	0.032258	0.064516	0.107996	0.005263
Fahadullah	0.048387	0.00198	0.032258	0.064516	0.107996	0.005263
Baba Imran	0.032258	0.053433	0.032258	0.032258	0.088266	0
Nasir	0.032258	0.053433	0.032258	0.032258	0.088266	0
Ismail Khan	0.032258	0.00198	0.032258	0.032258	0.041537	0
Ajmal Amir Kasab	0.032258	0.00198	0.032258	0.032258	0.041537	0

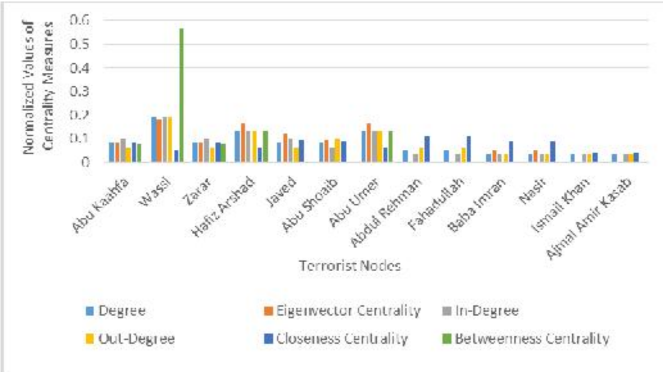

Fig. 3. Distribution of Centrality Measures for 26/11 Network

Individual values of each of these centrality measures, can help in identifying the relative importance of each node compared to others. But all the measures are unable to identify the same node as the key player/leader, also results in different rankings of nodes. For example, in 26/11 network, Wassi is identified as a key player, as its higher values of Betweenness, Degree, Eigenvector, In-degree and Out-degree centrality, but on the other hand, Abdul Rehman and Fahadullah are the key players according to the higher value of Closeness centrality.

For obtaining the overall/final ranking of nodes, priorities can be assigned to these centrality measures using the decision maker's subjective judgements as an input. For this purpose, AHP is used as a multiple attribute decision making technique.

B. Applying AHP on 26/11 network

Now, for finding the overall ranking of terrorist nodes for 26/11 network, decision hierarchy is framed as shown in Fig. 4.

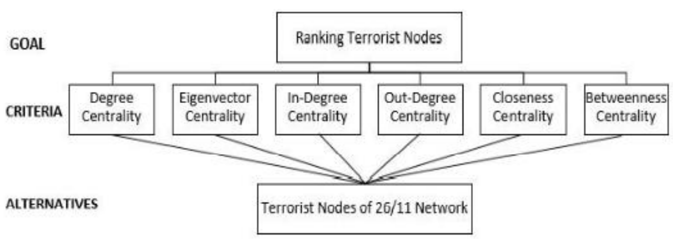

Fig. 4. AHP Decision Hierarchy for 26/11 Network

Above mentioned six centrality measures are considered as our decision criteria and all thirteen terrorist nodes are considered as alternatives for achieving our decision goal. Based on the work done by Fox and Everton [18] and using Saaty's nine point scale [15] pairwise comparison matrix for our six decision criteria is generated, as shown in Table V. These pairwise comparisons are based on the preferences of each centrality measure over other, usually decision makers consider for ranking nodes in various social networks.

TABLE V. Pairwise Comparison Matrix for Criteria

	Degree	Eigenvector	In-Degree	Out-Degree	Closeness	Betweenness
Degree	1	1/4	2	2	1/2	1/4
Eigenvector	4	1	4	4	2	1/2
In-Degree	1/2	1/4	1	1	1/3	1/4
Out-Degree	1/2	1/4	1	1	1/3	1/4
Closeness	2	1/2	3	3	1	1/2
Betweenness	4	2	4	4	2	1

Our pairwise comparison matrix is consistent, as the value of consistency ratio, CR is 0.021 (i.e. less than 0.1)

For 6 criteria and 13 alternatives, using eigenvector method criteria weights (in form of 6 X 1 matrix) are calculated as shown in Table VI.

TABLE VI. Criteria Weights

Criteria	Criteria Weights
Degree	0.094
Eigenvector	0.269
In-Degree	0.062
Out-Degree	0.062
Closeness	0.169
Betweenness	0.341

In order to obtain the final ranking of 26/11 terrorist nodes, criteria weights (6 X 1 matrix, in Table VI) is aggregated with calculated centrality values of each terrorist nodes (13 X 6 matrix, in Table IV), using matrix multiplication.

The final AHP score values (13 X 1 matrix) and final ranking of all terrorist nodes of 26/11 network is shown in Table VII.

TABLE VII. Final Ranking of Terrorist Nodes for 26/11 Network and their AHP Scores

Terrorist Name	AHP Score	Final Ranking
Abu Kaahfa	0.080583	4
Wassi	0.29367	1
Zarar	0.080583	5
Hafiz Arshad	0.127954	2
Javed	0.066517	6
Abu Shoaib	0.058236	7
Abu Umer	0.127954	3
Abdul Rehman	0.031202	10
Fahadullah	0.031202	11
Baba Imran	0.036423	8
Nasir	0.036423	9
Ismail Khan	0.014627	12
Ajmal Amir Kasab	0.014627	13

The final ranking of terrorist nodes based on calculated AHP score is visualized in social network graph (node size ordered by AHP score) as shown in the Fig. 5, using NodeXL [23] and distribution of final ranking are shown in Fig. 6.

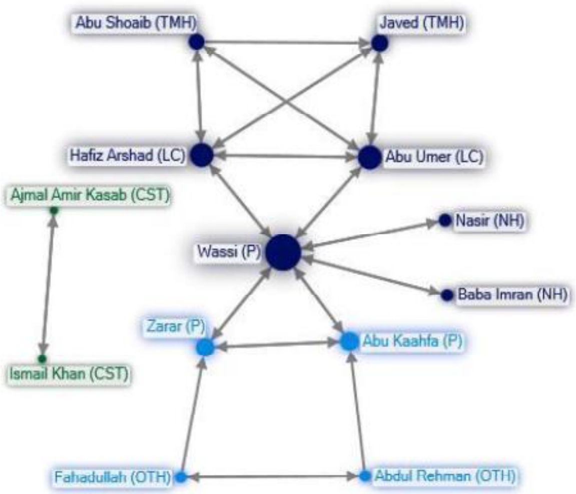

Fig. 5. Social Network Visualization of Final Rankings using AHP for 26/11 Network

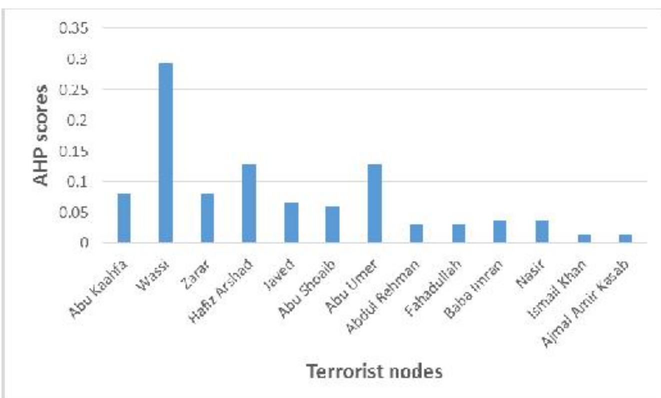

Fig. 6. Distribution of Final Rankings for 26/11 Network

Based on this study, it is found that Wassi, with highest AHP score is the most important individual, as he was handling the entire operation. Other key players in top 5 ranking, are Hafiz Arshad, Abu Umer, Abu Kaahfa and Zarar. The result represents the overall ranking of terrorist nodes based on the subjective judgments over considered six centrality measures as our decision criteria.

These rankings are subjected to change with the deviation in pairwise comparison of decision criteria. Sensitivity analysis using controlled trial and error method can be used to assess the change in rankings with variation in subjective judgments of the criteria and finding the cut-off point, affecting the rankings.

IV. Conclusion

SNA is one of the most powerful and effective analytical tool for studying various complex terrorist networks and organization. SNA Centrality Measures have been frequently used for identifying the key players/leaders and ranking of terrorists based on various terrorist networks/activities. Individual values of each of these centrality measures leads in identifying different nodes as the key players/leaders, which results in different rankings of nodes. So, for obtaining the overall cumulative ranking, based on the combined effect of each of these centrality measures, AHP can be used in addition to SNA. AHP is found out to be an effective technique, for identifying key players/leaders and ranking of nodes in various social networks, based on several criteria/attributes and subjective or objective comparisons over them.

In our work, we analyzed 26/11 Mumbai terrorist network using Analytical Hierarchy Process in addition to existing SNA Centrality measures, for finding the overall ranking of all 13 terrorists involved in the attack and identifying the key players/leaders among them. Ranking we got is based on the subjective judgments over considered six centrality measures as our decision criteria. Sensitivity analysis with trial and error method can be used to deal with changes in ranking with changes in subjective judgements for our decision criteria.

Though the data used in this study is small (13 nodes, 17 edges), further, the approach can be applied for large datasets. In future, some other multiple attribute decision making techniques (other than AHP) can be considered with SNA for finding key players and ranking nodes. We believe that, AHP when applied with SNA can be very effective in counter-terrorism applications, especially in, finding key players/leaders and ranking of terrorists in terrorist networks.

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