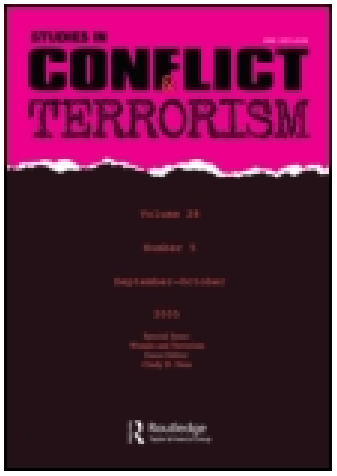

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A Social Network Analysis of Jemaah Islamiyah: The Applications to Counterterrorism and Intelligence

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This article attempts to contribute to and advance the growing literature on social network analysis and terrorism studies, through a social network analysis of the Jemaah Islamiyah cell that was responsible for the Bali bombings in 2002. In doing so, the article endeavors to provide a potential framework for the intelligence analysis of terrorist cells. Such a framework will assist in (1) understanding the communication and structure of such cells and (2) assist in predicting the likely outcomes of terrorist cells when employed in real-time intelligence analysis.

Social Network Analysis

There is an area within the social sciences that aims at understanding exactly how groups of individuals operate and consequentially, how they behave. This area is social network analysis, a methodological form of analysis that fuses mathematics, anthropology, psychology, and sociology. A "Social Network" can be defined as "a finite set or sets of actors and the relation or relations defined on them,"[1] where individuals are reduced to nodes, and their relationship to links (or lines). Therefore, social network analysis is "a mathematical method for 'connecting the dots' . . . [and] allows us to map and measure complex, sometimes covert, human groups and organization."[2] The method focuses on uncovering the patterning of people's interaction,[3] and correctly interpreting these networks assists "in predicting behaviour and decision-making within the network."[4] Furthermore, the "ability to understand and predict behaviour of members in a social network allows the analyst to evaluate specific courses of action that will influence the members of a social network in a desirable manner."[5] Steven Aftergood, of the Federation of American Scientists, claims that social network analysis "provides a useful way of structuring knowledge and framing further research. Ideally it can also enhance an analyst's predictive capability."[6] This article will briefly discuss the development of social network analysis within the intelligence and counterterrorism fields, and present a framework for the analysis of small-scale terrorist networks (cells) through the analysis of the Jemaah Islamiyah (JI) cell that operated in Bali, Indonesia, in 2002. This article has been approached through an Australian perspective, and has thus chosen to examine JI through social network analysis

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due to the group's clear and present threat to Australian assets, institutions, and citizens in Southeast Asia. The cell that conducted the 2002 Bali bombing was selected because it represents the largest and most coordinated attack that the group had undertaken to date.

Intelligence and Counterterrorism Applications

There has been an abundance of social network analysis research into crime, intelligence, and criminal networks, largely stimulated by Sparrow's[7] work on the application of network analysis techniques to intelligence analysis, which focused on the identification of network vulnerabilities within the different types and forms of criminal networks. Sparrow asserted that intelligence agencies have remained largely unsophisticated in their use of analytical concepts and frameworks, stating that social network analysis has a lot to offer intelligence agencies in this area through its ability to discover who is central within organizations, which individual's removal would most effectively disrupt the network, what role individuals are playing, and which relationships are vital to monitor.[8] Despite these important applications, Sparrow claimed there was little research overlapping the two fields. Sparrow exhibits three contentions within his article; the first is the pertinent application of social network analysis to intelligence analysis, the second is that there is significant opportunity within the field for adapting network analysis to the intelligence field, and finally, that such a collaboration would be extremely beneficial to both fields.[9]

Sparrow discussed the vital characteristics of covert or criminal networks that separate them from overt networks. These were: "Size," which noted the networks may be extremely large, spanning thousands of nodes; "Incompleteness," which details that the nature of covert cells entails that some links within the network will be missed by intelligence gathering methods; "Fuzzy Boundaries," implies that the borders of any covert network will be unclear, with individuals belonging to different groups and different networks, and "Dynamic," meaning that the network is constantly moving and changing, rarely static, with the interactions between individuals strengthening and weakening over time.[10]

Since Sparrow there have been several attempts at examining criminal and covert networks within the social network analysis literature, such as Baker and Faulkner's study of illegal networks within the heavy electrical equipment industry,[11] Klerks's study on varying criminal organizations and the approaches to examining these networks, and Deckro and Renfro's social network analysis of the Iranian Government.[12] Despite the application of social network analysis to military, crime, and criminal networks areas, as well as the dire necessity to gain the some ability to predict terrorism and understand how these groups operate, little research into social network analysis has been undertaken within the terrorism studies field. This lack of application is indicative of criticisms of terrorism studies raised by Silke,[13] and Brannan, Esler, and Strindberg,[14] which aim at the lack of empirical, quantitative, and substantive analysis within the field. Ultimately, this deficiency results in a scarcity of explanative and predictive studies.

Of the literature that does exist, Arquilla and Ronfeldt were among the first to take up the challenge. Arquilla and Ronfeldt,[15] in a book entitled *Networks and Netwars: The Future of Terror, Crime, and Militancy*, synthesized previous work, the sum of which introduced and developed the concept of "Netwar"[16] and its applications to terrorism, crime, and militancy. The authors assessed that "the field of network analysis, writ large, has been dominated by social network analysis, but organizational network analysis can be even more helpful for understanding the nature of netwar,"[17] then moving to shape a framework of "Organizational Network Analysis." This framework comprises five levels: the organizational level, the narrative level, the doctrinal level, the technological level,

and the social level.[18] The organizational network analysis framework differs from social network analysis in that it does not employ the use of robust empirical methods and mathematics to measure the values of the network, but rather focuses on criteria such as the strategies and methods employed, and the information systems used in the network. Arquilla and Ronfeldt's work provided an important framework for the analysis into the networks of terrorist cells and groups. Despite the important research and attempted development of the network analysis area, this study failed to literally apply their theoretical approaches to terrorist or covert groups using any form of sociometric, organizational analysis, or graph theory.

Within this sparse area of literature, there have been important applications between the fields of social network analysis and terrorism studies that have expanded the integration and cohesion between the two fields. Works such as Carley, Reminga, and Kamneva's[19] study examining the forms of disruption and destabilization applicable to dynamic and covert networks, and Tsvetovat and Carley's study focusing on the success of such destabilization techniques in structurally equivalent networks, are examples of work that theoretically apply social network analysis to covert and terrorist organizations.[20] Another significant application is Van Meter's examination of the varying forms of link and network analysis that have been employed by intelligence agencies in the analysis of covert networks. Van Meter promoted the integration or at least acknowledgement of academia's potential applications to the "closed" area of intelligence.[21] Although these applications have contributed to the development and coordination of social network analysis and terrorism studies, there has been a succinct lack of substantive application of social network analysis to specific existing or historical cells within the area.

The first such social network analysis of terrorism that applied graph theory, network and sociogramatical analysis to a non-fictional cell[22] was Valdis Krebs'[23] analysis of the 11 September Al Qaeda cell. Through this study, Krebs offered the most profound social network analysis to date of a terrorist organization, in that it applied a substantive framework to a real terrorist cell, moving from the previous studies that focused their studies on theoretical cells. The significance of this study is verified through work undertaken by Vos Fellman and Wright[24] and Farley,[25] the latter summarizing these substantive applications as necessary in that academic methods must aim at the assistance of law enforcement and intelligence agencies in the War on Terror.

Since the work of Krebs, there has been a small number other studies that attempt to map terrorist networks and cells. Carley, Dombroski, Tsvetovat, Reminga, and Kamneva in 2003 examined an Al Qaeda network that undertook an embassy bombing in Tunisia, and examined destabilization techniques of this network.[26] In a 2005 study, Carley mapped the communication and interaction within a 2002 Al Qaeda network through dynamic network analysis.[27] In the same year, Carley, Diesner, Reminga, and Tsvetovat also examined a terrorist network in the Middle East through dynamic network analysis.[28] Despite these works, there still exists little literature in which substantive historical terrorist cells have been mapped and examined through either social network or other forms of network analysis.

It has been established that there has been very little application of social network analysis to real terrorist groups. Despite the potentially profound significance of sociogramatical and social network analysis to terrorism studies, there are only a small handful of substantive studies that employ such analysis. It has been established that social network analysis is a powerful tool capable of providing a predictive and explanatory value to the field of terrorism studies, and hence, provide the beginnings of an essential capability to terrorism studies, and its integration into real world intelligence analysis.[29]

An Analyst's Framework

The framework presented in this article will bypass a significant amount of the applicable mathematical and social network theory and not extend to the more complex operations within the social network analysis frameworks in an attempt to provide a basic initial framework for an intelligence analysis tool. Despite its relative simplicity, the framework holds true to the academic principles of social network analysis and sociogramatical theory.

Stage 1: Contextual Background

The first step in any attempt to analyze a social network is to construct a contextual background. This background must be accomplished in order to understand the physical environment of the network. The background should be constructed through a case study approach, which is among the oldest of methodological traditions within qualitative research. Although the case study and other biographical forms of analysis are not generally considered of great value in the search for predictive intelligence analysis, their value cannot be trivialized, as without a meticulous, detailed, and objective biographical database or background, any form of analysis will prove useless. The construction of the contextual background must examine all information on the cell at the micro- and meta-levels: the individual, the cell, and the group or organization.

According to Scott[30] there are three principal types of data within research: attribute data, relational data, and ideational data. Scott maintains that the data appropriate to social network analysis is relational data.[31] Relational data consists of the contacts, ties, and connections of the individuals within a network; these "relations are not the properties of the agents, but the systems of the agents [therefore,] . . . the methods appropriate to relational data are those of network analysis."[32] This relational data must be made up of all possible data, both open sourced and classified (where appropriate); however, care must be taken in the collection so that objectivity remains paramount. Speculations and assumptions in the documentation of the interaction, communication, and relations between the subjects must be avoided at all times.

The contextual background of the JI Bali cell is far too extensive for presentation in this article; however, an abbreviated version will be presented to qualify the relational data that was synthesised from the full contextual background.[33]

Jemaah Islamiyah. JI was formed from the Darul Islam separatist movement in Indonesia during the 1950s. The goal of Darul Islam was the creation of an Indonesian Islamic state, and the movement was responsible for several uprisings through the 1950s and 1960s in Indonesia.[34] Although Darul Islam was suppressed and forced to operate underground during the late mid-1960s, several armed militant organizations formed from the group in the mid to late 1980s; one of these was JI. JI established radical Islamic boarding schools, and expanded their influence into Malaysia and throughout South East Asia.[35]

JI recruits trained in Afghanistan from 1985, after being tunnelled through *Makhtab al-Khadamat lil Mujahideen al-Arab* (Afghan Services Bureau) to Camp Saddah, in which recruits were schooled in a three-year training course that consisted of weapons, tactics, and explosives instruction, combined with strict *salafist* indoctrination.[36] The last class for Afghan training of JI members arrived in 1991, following the Soviet withdrawal.[37] The subsequent year, following a disagreement between JI leader Sungkar and another senior

Darul Islam leader, Ajengan Masduki, Sungkar established JI as an organization distinct from Darul Islam.[38] JI now had the unambiguous goal of establishing a pan-Islamic state in Southeast Asia.[39]

From 2000, JI attempted to assassinate the Philippines Ambassador to Indonesia, detonated 38 bombs in churches across the Indonesian archipelago,[40] and attempted to assassinate Indonesian President Megawati Sukarnoputri.[41]

2002 Bali Bombing Cell. In the late evening of 6 October, Amrozi, Azahari, Dulmatin, Imron, and Mubarok arrived in Bali with the L300 van that was to be used in the execution of the operation and (with the exception of Ali Imron) met with Samudra, Idris, Abdul Ghoni, and Umar Patek at the Hotel Harem in Denpasar to ensure everyone was up to speed with the security plan and their operational tasks.[42] Following this meeting, the group split up. The bombmakers, Azahari and Dulmatin, left for a large rented house at 18 Pulau Menjangan Street, accompanied later by Ali Imron. Amrozi and Mubarok left for a residence on Jalon Gatot Subroto in Denpasar.[43] In the Pulau Manjangan Street house, Ghoni, Patek, and Sarijo had already completed the mixing of the chemicals for the bomb experts and were to assist in the construction of the device.[44] The commanders of the operation, Samudra (field commander) and Idris (logistics commander), stayed in the Muslim quarter of Denpasar behind the Banyuwangi café and food stall in Jalan Pulau Pinang.[45]

The support group of the operation, Team Lima, were already in place. This group consisted of Octavia, Junaedi, Hidayat, Rauf, and Anasan, and were Samudra's protégé's who he had recruited and trained himself.[46] This group was to provide any necessary support for the operation, with Arnasan having already volunteered for martyrdom in the operation.[47] Three members of this group were established in a small unit in a communal compound at 10 Jalan Marlboro, in the outskirts of Denpasar, with the other two members situated in another location.[48]

Every member of the operation used a Balinese alias, and was addressed and addressed others by their aliases. They communicated using code words, referring to the bomb as *dodol kudus*, a type of Indonesian fruit cake. The main form of communication between each section of the cell and Samudra and Idris was SMS.[49] They changed their numbers frequently through sim cards Idris purchased at the Intikom phone shop in Denpasar.[50] If a call was received from an unknown number on a certain sim card, it would be changed immediately.[51]

In the following days, the house at 18 Pulau Menjangan Street was a hive of activity; Ghoni, Patek, Sarijo, Azahari, and Dulmatin were constructing the Vehicle Based Improvised Explosive Device (VBIED) to be used. Imron was also at the residence to assist in the construction process. The security was tight in this house, Patek and Sarijo did not know exactly who Azahari was, calling him "Alan" or "Lan." The six men never left the house[52] and constantly had someone on guard.[53] The mixed chemicals were packed into the plastic filing cabinet shelves that Mubarok and Amrozi had brought in the L300 from Tenggulun. The 4 drawers of each of 12 filing cabinets were filled with the explosive mixture and TNT chargers connected by around 150 meters of Pentaerythritol Tetranitrate–filled detonation chord. There were 94 Cyclotrimethylene trinitramine electric detonators attached to the TNT.[54] These filing cabinets were then positioned inside the L300.

Idris and Samudra visited Amrozi and Mubarok in Jalan Gatot Subroto on several occasions, bringing them food.[55] The pair also visited the bomb-building house on a couple of occasions to check the status of the operation.[56]

At some point during the operation, Muklas (JI head of operations in Singapore and Malaysia [Mantiqi 1]) alerted Idris via SMS that he was going to travel to Bali to visit the

group for a period of three days. During this visit, he was subjected to the same security procedures as the rest of the cell, often kept in a room on his own and isolated from the other individuals. Idris picked him up from the bus station in Denpasar, taking him to a small house where he later returned with food and Amrozi. Muklas also met another man at this point but they did not exchange names and Muklas did not know him. The following night, on 9 October, Muklas was taken on a surveillance run of the intended targets, Paddy's Bar and the Sari Club on Kuta,[57] and later (with Idris)[58] to visit the bomb construction team on Pulau Menjangan Street. Before his departure by bus, Muklas very briefly spoke to Ali Imron and Samudra.[59]

10 October was a busy day. The bomb was being loaded into the L300, and the device for the Paddy's Bar bombing was being constructed by Dulmatin and Azahari. The Paddy's Bar device was a vest loaded with about one kilogram of TNT. Each device was wired to a mobile phone to allow for the detonation by Idris from a distance.[60] Samudra met with Team Lima, and Rauf, Junaedi, Octavia, and Hidayat were instructed to return to their homes in Java. 10 October also saw the arrival of Feri, a friend of Ali Imron's from the Al-Islam school in Tenggulun who was recruited by Samudra to be the suicide bomber for the Paddy's Bar bomb.[61] By the evening of 10 October, all of the devices were ready, as were all elements of the operation. The JI members began to leave Bali that night, and by the afternoon of the following day, only Samudra, Ali Imron, Idris, Arnasan, and Feri remained on Bali.[62]

This operation was executed on 12 October 2002. Feri walked into Paddy's Bar on Kuta Beach, detonating the explosives in his vest, instantly killing eight patrons. As patrons poured out of the surrounding nightclubs and bars to investigate, Arnasan detonated the 1,000 kilograms of TNT and ammonium nitrate in the L300 VBIED just outside the Sari nightclub. The operation killed 202 people including 88 Australians.

Stage 2: Relational Data, Codification, and Visualization

The second stage in social network analysis concerns the storage and classification of the relational data collected through the aforementioned processes and data sources. The relational data must be codified and then stored in an adjacency matrix. The data is coded according to interactional criteria. These criteria include "Transactional Content" and "Frequency and Duration of Interaction."[63] The transactional content measure concerns the exchanges between the actors that define that relationship,[64] and are essentially the "substance" of the interaction. These exchanges can be the exchange of information, or simply contact that concerns the operation that is under investigation. These interactions can be through the use of telecommunications, Internet, letters, and through face to face and indirect contact.[65] It is the frequency and duration of these interactions that are measured by the second interactional criteria (Frequency and Duration of Contact).[66] Through this criteria, these interactions are given a value to qualify the strength of the interactions that are occurring between the individuals. For the codification of the JI cell, the strength of relationship ranged from 1 to 5 (Table 2). The recording of the interaction of the cell began following the meeting in the Hotel Harem in Denpasar on 6 October, when the group was considered to go "operationally covert," and concluded when the majority of the group had left Bali before the implementation of the operation on 11 October 2002.

Table 1 demonstrates the binary relations between the individuals within the Bali cell and illustrates merely whether a relation did or did not exist during the covert period. Table 2 demonstrates the strength of the relations between the individuals, with a score of 1 signifying the weakest relationship such as a single text message or a financial transaction,

Table 1

Jemaah Islamiyah binary relations

	MUKLAS	AMROZI	IMRON	SAMUDRA	DULMATIN	IDRIS	MUBAROK	AZAHARI	GHONI	ARNASAN	RAUF	OCTAVIA	HIDAYAT	JUNAEDI	PATEK	FERI	SARIJO
MUKLAS	0	1	1	1	1	1	0	1	1	0	0	0	0	0	1	0	1
AMROZI	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
IMRON	1	0	0	1	1	1	0	1	1	0	0	0	0	0	1	1	1
SAMUDRA	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1
DULMATIN	1	0	1	1	0	1	0	1	1	0	0	0	0	0	1	1	1
IDRIS	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	0	1
MUBAROK	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
AZAHARI	1	0	1	1	1	1	0	0	1	0	0	0	0	0	1	1	1
GHONI	1	0	1	1	1	1	0	1	0	0	0	0	0	0	1	1	1
ARNASAN	0	0	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0
RAUF	0	0	0	1	0	0	0	0	0	1	0	1	1	1	0	0	0
OCTAVIA	0	0	0	1	0	0	0	0	0	1	1	0	1	1	0	0	0
HIDAYAT	0	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	0
JUNAEDI	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0
PATEK	1	0	1	1	1	1	0	1	1	0	0	0	0	0	0	1	1
FERI	0	0	1	0	1	0	0	1	1	0	0	0	0	0	1	0	1
SARIJO	1	0	1	1	1	1	0	1	1	0	0	0	0	0	1	1	0

Table 2

Jemaah Islamiyah: Interactional criteria applied

	MUKLAS	AMROZI	IMRON	SAMUDRA	DULMATIN	IDRIS	MUBAROK	AZAHARI	GHONI	ARNASAN	RAUF	OCTAVIA	HIDAYAT	JUNAEDI	PATEK	FERI	SARIJO
MUKLAS	0	2	2	1	1	5	0	1	1	0	0	0	0	0	1	0	1
AMROZI	2	0	0	2	0	4	5	0	0	0	0	0	0	0	0	0	0
IMRON	2	0	0	3	5	3	0	5	5	0	0	0	0	0	5	1	5
SAMUDRA	1	2	3	0	2	5	2	2	2	2	2	2	2	2	2	0	2
DULMATIN	1	0	5	2	0	2	0	5	5	0	0	0	0	0	5	1	5
IDRIS	5	4	3	5	2	0	2	2	2	0	0	0	0	0	2	0	2
MUBAROK	0	5	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
AZAHARI	1	0	5	2	5	2	0	0	5	0	0	0	0	0	2	1	2
GHONI	1	0	5	2	5	2	0	5	0	0	0	0	0	0	5	1	5
ARNASAN	0	0	0	2	0	0	0	0	0	0	2	2	2	2	0	0	0
RAUF	0	0	0	2	0	0	0	0	0	2	0	2	2	2	0	0	0
OCTAVIA	0	0	0	2	0	0	0	0	0	2	2	0	2	2	0	0	0
HIDAYAT	0	0	0	2	0	0	0	0	0	2	2	2	0	2	0	0	0
JUNAEDI	0	0	0	2	0	0	0	0	0	2	2	2	2	0	0	0	0
PATEK	1	0	5	2	5	2	0	2	5	0	0	0	0	0	0	1	5
FERI	0	0	1	0	1	0	0	1	1	0	0	0	0	0	1	0	1
SARIJO	1	0	5	2		2	0	2	5	0	0	0	0	0	5	1	0

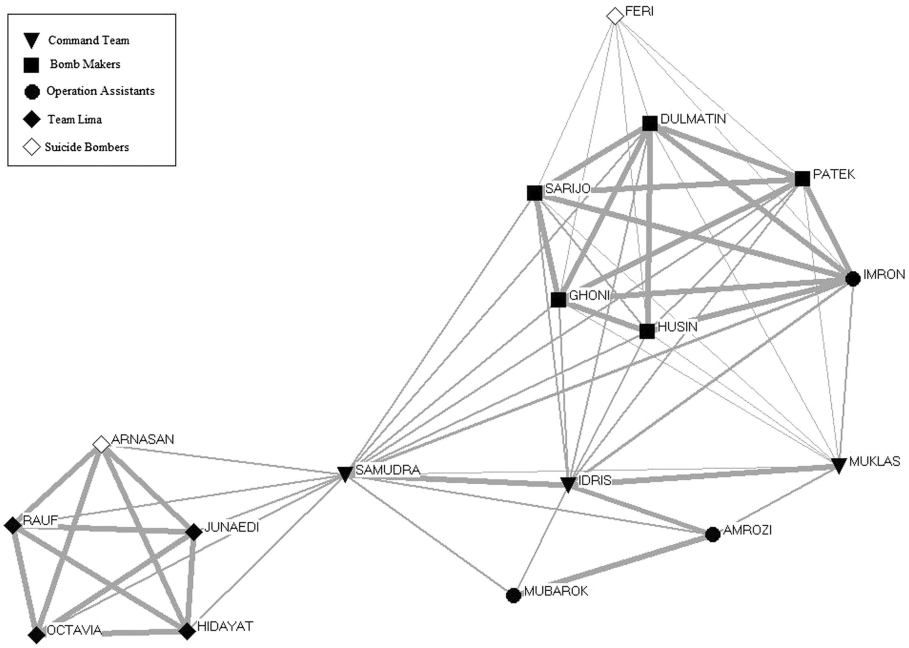

Figure 1. Jemaah Islamiyah Graph—Bali Operation October 6, 2002–October 11, 2002.

and 5 signifying the strongest relationship such as individuals who resided together, or individuals who had numerous weak contacts over the period in question.

Graphs—Visualization

A sociograph is a visual representation of a network developed through graph theory with the actors represented by nodes, and their relationships represented by links or lines. Sociogramatical analysis originated through "Gestalt" theory in psychology, principally through the work of Kohler[67] in 1925, and was developed through group dynamics approaches in unison with structural functionalist theory. This theory was later developed through the work of Moreno[68] and Lewin,[69] who developed the sociogram and sociometric analysis. The method was refined through Harvard structuralists, principally Harrison White and his students through the 1960s.[70] Figure 1 illustrates more clearly the communication, interaction, and structure of the cell. This graph was constructed through the use of UCInet Version 6.85,[71] using the tabulated relational data presented in Table 2.

Stage 3: Network Characteristics

The analysis within this framework entails seven structural criteria that will be used in the analysis:

(1) Size; (2) Density; (3) Degree of Connexion; (4) Centrality; (5) Closeness; (6) Betweenness, and (7) Clusters.

Size. Size can be defined generally as the number of nodes within a network or data set. Boissevain describes the size measure as the "most important structural criterion of

a . . . network . . . this is because the other criteria are calculated as a proportion of the total possible or actual links in the network."[72] This measure was limited in this project through the network being limited to actors within the terrorist cell or those involved with terrorist activities in association with the cell. This strict procedure for the inclusion of members in the network aims to limit the fuzzy boundaries of covert networks discussed by Sparrow previously. These limitations of size allowed for the analysis of the cell itself, and not extend to the group's wider terrorist networks.[73]

Density. Density is described as the "the average proportion of lines incident with nodes in the graph,"[74] or "the extent to which links that could possibly exist among persons do in fact exist."[75] The use of density can indicate how covert a cell is, for example, Krebs' analysis shows that the 11 September cell had a low density, implying that the removal of a node is less likely to compromise the rest of the network. As discussed, low density networks are not as efficient as networks of high density. Density is measured by the following equation:[76]

$$D = \frac{L}{g(g-1)/2}$$

where D is density; L is the total number of lines present; and g is the total number of nodes within the network.

Degree of Connexion. This criterion allows the measure of the average number of relations each member has with other members of the network.[77] This criterion can qualify the results of density equations, and allow further comparative analysis between networks. The degree of connexion (d) is calculated by:

$$d = \frac{2L}{g}$$

Actor Level Degree Centrality. Actor level degree centrality is the level at which a node is accessible to the persons in the network. Centrality is affected not only by the size of a network, but by the formation and shape of the network.[78] This measure assists the analyst in identifying the leaders within networks; this does not entail that they necessarily hold the power in the relationships or indeed the network; however, an individual's centrality indicates a critical importance within the network. The equation for the calculation of centrality is presented by Faust and Wasserman is:[79]

$$C_D(n_i) = d_i(n_i)$$

where $C_D(n_i)$ is the Degree of Actor Level Centrality Index for node "i" and $d_i(n_i)$ is the degree of node "i."[80] The higher the value of $C_D(n_i)$, the more central that individual is. In order to have the ability to compare the different centrality indexes, the result of this equation, $C_D(n_i)$, will be standardized to a percentage or proportion.[81] The equation for the standardized actor level centrality index is:

$$C'_D(n_i) = \frac{d_i(n_i)}{g-1}$$

Actor Level Closeness Centrality. Closeness is a criterion applied to the individuals within a network, and describes how close an actor is to others in the network, or the ability of actors within a network to access others.[82] The equation for closeness is presented in the following, and was developed by Sabidussi in 1966:[83]

$$C_C(n_i) = \left[\sum_{j=1}^{g} d(n_i, n_j)\right]^{-1}$$

where C_C (n_i) is the "Actor Level Closeness Centrality Index," g is the total number of actors within a network, and $d(n_i, n_j)$ represents the geodesic distance between node "i" and node "j." The result of this equation, C_C (n_i), is then multiplied by $(g - 1)$, to give a standardized result as a percentage.

Actor Level Betweenness Centrality. Betweenness is another measure of an individual's activity/ability within a network, measuring the ability to control the flow of information within a network. The equation for the calculation for betweenness, developed by Freeman in 1977,[84] is:

$$C_B(n_i) = \sum_{j<k} \frac{g_{jk}(n_i)}{g_{jk}}$$

where $C_B(n_i)$ is the "Actor Level Betweenness Centrality Index" for node "i," g_{jk} is the number of geodesies linking nodes "j" and "k," and $g_{jk}(n_i)$ is the number of geodesies linking the two actors that include the node "i." This equation calculates the probability that node "i" will be between an interaction between the other nodes within the network. Once again, $C_B(n_i)$ is standardized to a percentage, $C'_B(n_i)$, ("Standardised Actor Level Betweenness Centrality Index") by:[85]

$$C'_B(n_i) = C_B(n_i)/[(g - 1)(g - 2)/2]$$

Clusters. Clusters are simply areas of a network with a higher density in relation to other areas or cliques within the network.[86]

Analysis—Jemaah Islamiyah 2002 Bali Cell

The following results have been synthesized from Tables 3 and 4, which illustrate the relationships between the members of the JI cell between the 6th and 11th of October 2002 using the equations and measurements presented earlier.

The size of the JI Bali cell was 17, a large cell, perhaps unnecessarily so, with at least 4 individuals not playing any involvement in the operation. Figure 1 does indicate

Table 3
Overall structural criteria

	Cell size	Density	Degree of connexion
Score	18	43.382%	6.941

Table 4
Ranked centrality measures

	Centrality (standardized)	Betweenness (standardized)	Closeness (standardized)
SAMUDRA	93.750	50.972	94.118
IDRIS	62.500	5.139	72.727
MUKLAS	56.250	1.944	69.565
ALI IMRON	56.250	1.389	69.565
DULMATIN	56.250	1.389	69.565
AZAHARI	56.250	1.389	69.565
PATEK	56.250	1.389	69.565
GHONI	56.250	1.389	69.565
SARIJO	56.250	1.389	69.565
FERI	37.500	0.000	48.485
ARNASAN	31.250	0.000	57.143
JUNAEDI	31.250	0.000	57.143
ABDUL RAUF	31.250	0.000	57.143
OCTAVIA	31.250	0.000	57.143
HIDAYAT	31.250	0.000	57.153
AMROZI	25.000	0.278	55.172
MUBAROK	18.750	0.000	53.333

through the size of the cell, and the roles that each of the members played, that contingency plans were available, were the cell to be disrupted. These contingency roles were taken up by Team Lima (excluding Arnasan) and Amrozi and Mubarok. These individuals were in place to take over any unskilled roles (mixing/packing chemicals, driving, surveillance, making purchases, or suicide bombing[87]) that were vacated through other members being compromised, falling ill, or backing out of the operation. As the graph demonstrates, these individuals were kept significantly isolated from the rest of the group.

The density of the cell was 43.382%, which indicates a mix between efficiency and covertness. This density score is largely due to the two all-channel clusters of Team Lima (Octavia, Arnasan, Junaedi, Hidayat, Rauf, and Samudra) and the bomb construction team at the Jalau Manjangan Street house (Patek, Imron, Azahari, Dulmatin, Ghoni, and Feri). These clusters were necessary, at least in the case of the Manjangan house, as the precise and time efficient construction of the explosive devices required heavy coordination and efficiency. Measures were taken within this cluster to attempt to counter the low levels of covertness that this density created. All individuals were operating under aliases, using mobile phones to communicate with individuals outside the cluster, and above all, these members never left the house (with the one exception following the explosion inside the garage). Due to the reasonably high (43.328%) density score, the cell was less covert. This would suggest that the exposure or detection of one of the members by authorities, although not making a significant impact on the cell's overall efficiency and operation, would run the risk of exposing multiple members of the cell, especially if that member was in the Manjangan residence. This observation is supported by the high degree of connexion score of the cell, 6.941, that the exposure of one node within the cell could potentially lead to almost seven other nodes, and from these nodes the entire cell would be exposed.

From Table 4 it is clear that Samudra was the most central and active individual within the network, with the highest ability to access others, and the greatest control over the flow of information in the network. The most significant aspect of this finding is that by a significant margin, Samudra had the greatest ability to access the other individuals within the network. This result was exclusively due to his connection to Team Lima, and the suicide bomber Arnasan. Although this cluster did not have a major role to play in the operation (Arnasan excluded), they were the backup for the operation, had anything gone wrong. Samudra's centrality scores are further evidenced by Figure 1 in which Samudra resembles the hub in a star network.

Idris, in his role as logistics commander, yielded high centrality scores also, however these were not as significant as those of Samudra. The cell was quite centralized overall, with the members of the Palau Manjangan residence (bomb construction team) seemingly the center of the operation. The lowest centrality scores were reserved for the contingency members who were kept to the periphery except when called on for assistance. Mubarok had the lowest scores as he was kept very isolated and did not play any significant part in this stage of the operation.

Findings

This analysis of the 2002 JI Bali bombing cell between 6 October and 11 October, 2002, or the cell's "Covert Stage," uncovered four main findings. The first finding is that Samudra and Idris were the most important individuals within the cell, specifically due to their high centrality scores. The second finding is that the high density and degree of connexion scores indicated the cell had a higher focus on efficiency and was less covert. This structural integrity would allow the group to recover from the loss of one or even two members, with only the loss of some efficiency. However, if this loss was through the compromise of a node by a counterterrorism authority, the high density and degree of connexion would rapidly lead to the identification of a majority of the cell. The third finding is that Samudra was the weakest point in the cell, and his capture would possibly have led to the isolation of Team Lima (which included the suicide bomber and contingency nodes) and the loss of the most active and centralized member of the network. It is important to note, however, that covert networks have the ability to heal themselves in the event of the loss of a node. It is most likely that Idris would have been able to accommodate Samudra's role in the operation, in the event of this loss, reconnecting a link with Team Lima. With this in mind, the removal of both Samudra and Idris from the network would remove the two most important nodes within the network, and it can be assumed, would isolate the main group from the suicide bomber Arnasan, as well as the cluster in position to replace such individuals, damaging the cell to an almost inoperable state. The final finding is that the visit of Muklas to Bali unnecessarily involved a high ranking member, and was operationally unsound, however, it could have been justified by motivational and unification purposes that were required at this stage following disagreements and arguments among the cell members.

Applications

The social network analysis of the JI Bali bombing cell of 2002 measured the level of each cell member's activity, ability to access others, and the control over the flow of information within the network. The analysis also assessed the overall group's orientation toward either efficiency or covertness, and identified the group's leaders or most valuable nodes, as well as

the dense clusters, and the weaknesses within the network. From the identification of these criteria, specific counterterrorism applications can be constructed, such as the identification and targeting of dense areas of the network for maximum exposure and compromise, or alternatively targeting critical points in the network to sever connections between clusters or other sections of a network. This is the most valuable aspect of social network analysis, the method's visualization and mathematical measures allows the analyst to evaluate the best responses and tactics in attempting to disrupt the cell to the point at which it is no longer able to function.

Although this analysis has provided important insight into the 2002 JI Bali cell, further applications can be drawn from this analysis, when attempting to predict how future JI cells would operate. First, the JI cell would make preparations outside or in a remote area of the country of intended operation, and enter the major city or target area as a compartmentalized network consisting of several very dense or all-channel[88] clusters focusing on efficiency and work as quickly as possible to complete the preparations and disperse before the implementation of the operation took place. These sections would be linked by the field commander or logistics commander. For a cell that does not have an extremely high level of covertness, such preparations would almost certainly have to take place in an area where members of JI could remain inconspicuous; this is especially relevant for a JI cell operating in a Western nation, particularly Australia. As seen with Samudra in the Bali operation, such a cell would have one or two high-ranking members, who would be the most central and important nodes within the network (controlling the communication between sections of the network), constituting structurally weak points. As well as Samudra and Idris, the Bali cell used high ranking individuals such as Muklas. Following the rise of JI's infamy from December 2000 (the Christmas Eve bombings) to October 2005 (the 2005 Bali bombing) such high ranking individuals may be used in the initial stages of planning, but not in the covert stage of the operation. Were the group to operate in a Western nation, they would certainly be smaller than the Bali cell, and the group would use local contacts to assist the cell members in the initial stages of the operation (as the group did in Bali). These individuals would be employed for local knowledge and the acquisition of resources locally. This finding encourages the continual surveillance of individuals known to have trained or associated with groups such as JI in both Southeast Asia and Western nations.

Further, social network analysis needs to be conducted on subsequent JI cells such as the 2003 Jakarta Marriott bombing cell, the 2004 Australian embassy bombing cell, and the 2005 Bali bombing cell, to increase the understanding of JI's covert network formations. It appears that subsequent operations resemble the network characteristics of the 2002 Bali cell in that the bomb was constructed (most likely by a dense cluster) close to the target area after the chemicals were transported from other areas, and that the field commander and logistics commander were on hand to witness the results. Following the many arrests resulting from the Bali bombing, Azahari became the field commander of operations, and Noor Din Mohammed Top became the logistics commander or chief strategist. Further research many identify a template JI formation, which will allow powerful predictive applications.[89]

The use of social network analysis in this article has aimed at identifying and analyzing the major structural and interactional features of a JI cell. This comprehension is necessary in the countering of JI operations both in Southeast Asia and Australia. Although a single analysis of one of many historical JI cells will not provide a succinct structural map of how future JI cells will operate, it does provide significant insight and understanding into the operation of the group. Further studies of such operations are encouraged by the author. Although the use of social network analysis looking at historical groups is

capable of providing some levels of predicability and foresight, the method is at its most powerful when employed in real time, allowing the clear visualization of the interactional, communicational, and structural cohesion of an operational cell, bestowing the analyst with a potent weapon of prediction in the fight against terrorism, and the ability to evaluate the best and most effective methods of disruption against a terrorist cell.

Notes

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20. M. Tsvetovat and K. Carley. "Structural Knowledge and Success of Anti-Terrorist Activity: The Downside of Structural Equivilance," *Journal of Social Structure*, 6 (2) (2005) pp. 23–28.
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40. S. Neighbour. *In the Shadows of Swords* (Sydney: Harper Collins Publishers, 2004), pp. 224–226.

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47. D. Goodsir. "Ruthless Enforcer Pulled the Strings," *The Sydney Morning Herald*, 11 September, 2003, p. 9.

48. Goodsir and Miller, "The Night Terror Touched Our Lives," p. 2.

49. Neighbour, *In the Shadows of Swords*.

50. Goodsir and Miller, "The Night Terror Touched Our Lives," p. 2.

51. Neighbour, *In the Shadows of Swords*, p. 286.

52. Apart from the one incident where a small amount of the explosives detonated, and the group left to demonstrate to inquisitive neighbors that the noise was of no significance.

53. Neighbour, *In the Shadows of Swords*, pp. 285–287.

54. "The Bali Bomber's Song," *Jakarta Tempo*, 18 February, 2003.

55. Goodsir and Miller, "The Night Terror Touched Our Lives," p. 2.

56. Neighbour, *In the Shadows of Swords*, p. 287.

57. *The Bali Confessions*. Four Corners, Australian Broadcasting Corporation, Sydney, 10 February 2003.

58. E. Chua. "Ex-UTM Don and Samudra Charged," *The Business Times*, 3 June 2003, p. 20.

59. Neighbour, *In the Shadows of Swords*, pp. 290–291.

60. Goodsir and Miller. "The Night Terror Touched Our Lives," p. 2.

61. Neighbour, *In the Shadows of Swords*, pp. 292–293.

62. Ibid., p. 293.

63. J. Boissevain. *Friends of Friends: Networks, Manipulators, and Coalitions* (Oxford: Basil Blackwell, 1974), pp. 28–33.

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65. Ties such as family, religion, and friendship are considered to be dormant during the covert stage of an operation, as the only interactions that bind individuals together are those that concern the operation. These are the interactions that can be tracked and monitored by counterterrorism authorities.

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67. W. Kohler. *The Mentality of Apes* (Mitcham: Penguin Books, 1925).

68. J. Moreno. *Who Shall Survive?: A New Approach to the Problem of Human Interrelations* (Washington: Nervous and Mental Disease Publishing Co, 1934).

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71. S. Borgatti, M. Everett, and L. Freeman. *Ucinet for Windows: Software for Social Network Analysis* (Harvard, MA: Analytic Technologies, 2002).

72. Boissevain, *Friends of Friends*, p. 35.

73. Such measures also ensure that the focus and length criticisms of case studies are abided by.

74. Wasserman and Faust, *Social Network Analysis*, p. 102.

75. A. Radcliffe-Brown. *Structure and Function in Primitive Society* (London: Cohen and West, 1952), p. 11.

76. Wasserman and Faust, *Social Network Analysis,* p. 101.

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78. Ibid., p. 41.

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80. This "degree" simply equates to the number of links the individual node possesses.

81. The standardization of results was devised by Beauchamp in 1965.

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85. Borgatti, Everett, and Freeman, *Ucinet for Windows*.

86. Scott, *Social Network Analysis*, p. 129.

87. This last role was reserved for the members of Team Lima.

88. Areas of a network with 100% density (every member interacts with every other member).

89. This is not unfeasible, as the operations are conducted by individuals with the same training and indoctrination (Afghanistan and Mindanao), and are often planned and executed by the same individuals.