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SOCIAL NETWORK ANALYSIS (SNA): CHARACTERISTICS AND EXAMPLE APPLICATION; THE “NETWORK EFFECT” HYPOTHESIS

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Abstract

This article delves into the nature of horizontality, delineating both its qualitative and quantitative features. Moreover, it is the first attempt to determine the preconditions for achieving the network effect, i.e., the impact generated solely by the connectivity between network participants.

Using social network analysis (SNA), it shows the mathematical properties of the entire network, as well as the features of all individual participants' positions in the network. Moreover, it demonstrates sociograms and their diverse visualizations.

Based on a case study of one of the vibrant networks, this article presents some indications for determining the criterion for the occurrence of the network effect, thus making the network effect metaphor tangible. It concludes with delineating the four-step dynamics:

- Instigating the spirit of connectivity, leading to a
- Bottom-up process of initiating a multiplicity of connections;
- The dense connectivity generates autocatalytic dynamics of cooperation,
- Resulting in the appearance of multiple value-added bottom-up projects that augment the mission of the organization and the goals of individual participants.

Applications for social and business sectors, as well as some indications for future studies, are reviewed.

Introduction

Social Networks

The significance of networks was flagged in the early 20th century, e.g., by sociologist Émile Durkheim, who introduced the concept of "social networks" (Freeman, 2004). In the second half of the 20th century, there was a rapid rise in studies on social networks (Barabási, 2003; Zheng et al., 2016). For example, Ronald Burt (1980) introduced the concept of network structure models, and Mark Granovetter (1983) studied the differences between weak and strong ties in networks, highlighting the significance of weak connections. Moreover, the idea of "small worlds"—close-knit circles as part of a larger network—emerged (Watts, 1999). Furthermore, Albert-László Barabási (2003), in his well-known book, examined the connectivity of networks encompassing diverse aspects of human activity. Manuel Castells' foundational book, *The Rise of the Network Society* (Castells, 2007), appeared at the beginning of the 21st century.

The second decade of the 21st century brought some studies on the benefits of networking: It is associated with a feeling of connectivity, reduces loneliness, and builds social capital (Burke et al., 2010); moreover, it provides a feeling of participation in circles of joy and happiness (Fowler & Christakis, 2008). Networking also augments creativity (Lee, 2014; Pulgar, 2001), especially through a large number of cross-unit ties in combination with a large number of cross-hierarchical ties (Aalbers et al., 2016). Social networks are currently seen as a significant fulcrum for innovation (*ibid*).

The Network Effect

The term "network effects" has become a popular, though quite vaguely defined, catchword. It is associated with having some extraordinary "power" (e.g., Trewin, 2022), sometimes juxtapositioned with "magic," e.g., "The magic that happens when users take on the work of growing networks to predominance because their transactional value is so clear" (Gosh, 2023) and "The magic of network effects is that they generate a positive feedback loop that results in super-linear growth and value creation" (Hoffman & Yeh, 2018).

The definitions of the network effect seem descriptive, referring to a metaphorical rather than tangible delineation: The network effect is a phenomenon by which a product's value depends on the number of users; it typically creates a positive feedback system, resulting in users deriving more value as more people join the same network (Katz & Shapiro, 1994; Shapiro & Varian, 1999). The network effect whereby increased numbers of people or participants improve the value of a good or service. The more popular a business or product grows, the more the users effectively act as salesmen, spreading the word about the entity or item (Banton, 2024). The network effect occurs when the value increases simply because the number of users increases, causing the network itself to grow; hence, the value depends on the number of users who leverage it (Stobierski, 2020).

Analytic Approaches to Social Networks

An analytic approach to social networks was introduced in the 1990s (e.g., Degenne & Forsé, 1999; Wasserman & Faust, 1994), called social network analysis (SNA). SNA is seen as a methodology or set of techniques for analyzing networks of people engaged in work and community situations (e.g., Tabassum et al., 2018). In the first two decades of the 21st century, interest in SNA grew exponentially (Camacho et al., 2020). It evolved from graph theory to a formal, conceptual approach to making statements about social properties and processes (Wasserman & Faust, 1994). The premise for this growing interest is the conviction that social behavior is largely the result of social ties and connections: Contact with other people shapes one's worldview and reinforces identity. Recently, SNA has been regarded as

an important tool for understanding the connections that influence our social, professional, and digital lives (Burt, 1980).

Within sociology, SNA is currently pivotal in exploring the structures of communities and organizational networks. It examines how social capital can influence social mobility and access to resources. The network approach in sociology also aids in understanding the diffusion process of innovations and behaviors, providing insights into how certain trends become widespread within a society (Whitehead, 2024). Additionally, SNA enables the identification and addressing of communication bottlenecks, fostering a collaborative work environment that encourages innovation and boosts productivity (Jatel, 2023).

SNA methodology is advantageous in both public and private sector research, as it is applied to study the structure and behavior of organizational networks (Schultz-Jones & Macpherson, 2006). SNA is also used in banking (Miranda et al., 2013) and leadership studies (Hoppe & Reinelt, 2010).

The Void and the Challenge: Tangible Definition of the Network Effect

Despite the advanced SNA approach, there is still a gap in identifying a tangible definition of the network effect. Some general insights are still more metaphorical than measurable, e.g., the conclusion that the network effect occurs when the value of the network increases simply because the number of users increases, causing the network itself to grow (Stobierski, 2020). This article aims to fill this gap and identify some qualitative and quantitative network effect (NE) criteria. Along these lines, it demonstrates the tangible manifestation of the network effect, i.e., that appropriate features may generate new bubbles of value-added horizontal cooperation. As a result, the cooperation between network participants may be perceived as an additional fulcrum for generating social change.

SNA Measures

SNA delivers information in three primary sections (Borgatti et al., 2024):[1]

1) The properties of a network as a separate whole;
2) The position and characteristics of individual network participants (referred to as "nodes" in SNA terminology);
3) Network sociograms, graphs, and visualization of various configurations.

Analyzing the Network as a Whole

Several network features are important to consider:

- Number of nodes

Number of connected and unconnected nodes

- Average degree

This refers to the average number of connections (called "edges" in SNA terminology) coming from individual nodes. A higher average degree indicates a more connected network.

- Network density

This is calculated by dividing the number of actual edges by the number of potential (possible) connections. The latter is determined using the factorial formula: $\frac{n!}{[(n-2!)*2!]}$. For example, in a network of $n = 5$ nodes, there are 10 potential connections. If there are three existing connections, the density is 3/10 potential connections = 0.33. A higher density indicates better connectivity among members.

[1] See also: http://www.orgnet.com/sna.html. Accessed 10 March 2025.

- Average path length

This measures how many nodes must be traversed to reach all other nodes, which is averaged over all possible paths, i.e., the average number of steps along the shortest paths for all possible pairs of network nodes. It represents the efficiency of information flow. Shorter average paths indicate better efficiency.

- Network diameter (closeness)

This is the average shortest distance between the two most distant nodes in the network. A smaller network diameter suggests greater closeness within the network.

- Structural cohesion

This refers to the minimum number of nodes that must be removed to disconnect the network.

Individual Participants and Their Position in the Network

Although not the purpose of this article, it is worth mentioning that SNA also enables quantifiable delineation of each individual position in the entire network, e.g., by:

- In-degree: The number of incoming connections to a node (i.e., how many other nodes are connected to this one).
- Out-degree: The number of outgoing connections from a node.
- Degree (total): The sum of the in- and out-degrees.
- Closeness centrality: This measures the distance from one node to all others in the network. It is calculated by dividing the number of nodes that can be reached (i.e., the total number of nodes in the network minus 1) by the sum of these distances. A larger value indicates greater centrality.
- Betweenness centrality: A measure of how often a node lies on the shortest path between pairs of nodes in a network. It counts the number of times a node lies on the shortest path between other nodes. A higher value indicates greater centrality.

Network Visualization

One of the early questions was how the global network is structured. Initially (from the late 1950s to the mid-1970s), there was a belief that large networks are random and that the majority of nodes have the same degree as the typical node does, following a bell curve (Barabási, 2003).

The next concept was the “small worlds” theory, which suggested that we are grouped into close-knit circles that are strongly inter-connected but only weakly linked to other (outside) circles.

Currently, the global network is perceived as a mixture of strongly connected hubs and less connected nodes, following a specific mathematical formula. This is known as a scale-free network. Scale-free networks usually provide better coordination and flow of information. They are resilient and impervious to failure, a property known as robustness (Barabási, 2003).

Analyzing graphs: What is available to see?

- Network structure: Hubs and holes

Visualizing sociograms through SNA provides opportunities to capture the structure of a network, i.e., high-degree hubs and how they are distributed. Identifying these hubs may help strengthen an organization, as they may be assigned important roles, such as aiding in mission fulfillment or information distribution. Are there weak or non-connected nodes? In the latter case, one might identify *structural holes*—the absence of ties between two parts of a network (Burt, 1980).

- Structural cohesion

A network's *structural cohesion* can also be analyzed, i.e., how many connections should be cut to segment the network? If one connection links two nodes, cutting it will split the network into two parts, which can be beneficial in situations like disease control; in this case, structural cohesion = 1. If there are at least two connections, then structural cohesion = 2, meaning two connections must be cut to disassemble the network. A higher level of structural cohesion augments the network's resilience.

- Node and connection attributes

Sociograms can display various node attributes, such as age, year of election, and degree. The size of nodes may be proportional to the value of the attribute (e.g., higher-degree nodes appear larger), or attributes can be represented using color. Additionally, arrows may indicate the direction of connections.

SNA Application: Case Study

Target Population

The target population was living Polish Fellows of the international organization Ashoka: Everyone a Changemaker (www.ashoka.org). One of Ashoka's missions is to identify and empower social entrepreneurs and innovators. From the launch of the Ashoka program in Poland in 1995 to November 2024 (the study date), 86 Fellows were elected, 77 of whom are still alive and were invited to participate.

The specifics of the Ashoka chapter in Poland are that the staff, as well as the Fellows, initiate multiple and diverse community-building actions. A selection of examples may be viewed on the website.[2] These initiatives involve meetings, including round-table discussions, and, in the long run, are usually taken by the Fellows into their own hands. The result is that the multiplicity and diversity of initiatives, as well as their community and comradeship ethos, instigated the environment of high connectivity value.

Survey

The questionnaire was uploaded to the online Google Forms platform. It asked for consent (e.g., for revealing their name or replacing it with a nickname) and also for demographic information. This was followed by two questions: One asking for contacts with other Polish Ashoka Fellows and the other about cooperation with them. The response was provided through a pop-down menu listing all living Ashoka Fellows. SNA was performed using the Gephi 0.10 application.

- Connections

The first question focused on participants' contact with each other:

"With whom from the Ashoka Fellows did you intentionally connect with over the last 10 years?

This question relates to intentional contacts: Personal, over email or phone, initiated by you or by the other person. It does not relate to accidental contact, e.g., at conferences or Ashoka Fellows meetings.

Select any number of people from the drop-down menu."

- Cooperation

The second question addressed cooperation:

"With whom from the Ashoka Fellows did you cooperate within this period of time?

[2] See: https://www.ashoka.org/pl-pl/nasze-dzialania (accessed 13 March 2025). A selection of previous initiatives is listed at the page bottom of the page.

Select any number of people (drop-down menu).”

- The rationale behind choosing these two questions: Hypotheses

The conjecture is that contacts are a valuable asset for building identity, fostering a sense of community, providing peer-to-peer support, spreading information, sharing successes and failures, and charging the battery.

Moreover, the conjecture is that cooperation may be an indicator of the value generated through the network. It shows how people collaborate, often bottom-up, to boost impact through new projects. A cooperation network can facilitate the smooth dissemination of new ideas and directions.

The aim was to grasp the measurable characteristics of the two networks (contacts and cooperation) and analyze what preconditions of the contacts network may foster autocatalytic dynamics, generating new bubbles of cooperation. This sort of autocatalytic process requires specific characteristics of the initial network— a subject of reflection in this study. Finally, the results serve to estimate possible network effect criteria.

- Formal data

The online Google Forms survey was launched on 26 July 2024, and continued until 16 September 2024. The survey was addressed to 77 living Ashoka Fellows in Poland, of whom 53 (68.8%) filled out the questionnaire.

Most of the participants agreed to reveal their names, except two, who asked for a nickname replacement.

Table 1 shows the statistics of the responses received.

Table 1. Survey statistics.

# of Polish Ashoka Fellows addressed		77
# of responses		53 (68.8%)
Those who completed the survey	Age distribution	33–84
	Average age (M) and standard deviation (SD)	M=59.1; SD=13.2
	Women	22 (41.5%)
	Men	31 (58.5%)
	Time span of election to Ashoka	1995–2024

It is important to note that the final responses also indicate many of those Ashoka Fellows who did not respond to the survey, as they were mentioned by those who did.

Results

The results below display the statistics of the two networks (connections and cooperation), as well as their visualization. The study also included the analysis of each particular participant’s position in both networks; however, the latter is not the subject of this paper.

Connections

Table 2 displays the statistics of the network’s connectivity.

Table 2. Measures of network connectivity.

# of nodes	77	Most of the 77 nodes are mentioned in the results, including those who did not complete the questionnaire. Most of these unresponsive nodes are mentioned by those who did fill it out, thus they are represented as connected.
# of edges	683	The total number of connections.

Average degree of all nodes	8.87	The average connectivity of all nodes in the entire network. This means that the average node has nearly 9 connections.
Network density	0.117 (11.7%)	The number of existing connections divided by all possible connections (how many edges there are, compared to all theoretically possible edges).
Average path length	1.95	The number of nodes that must be traversed to reach all other nodes, averaged across all possible paths (i.e., the lower the better).
Network diameter (closeness)	5	The average shortest distance between the two most distant nodes in the network (the lower the better).

Below is a connection graph of the entire network (Figure 1).

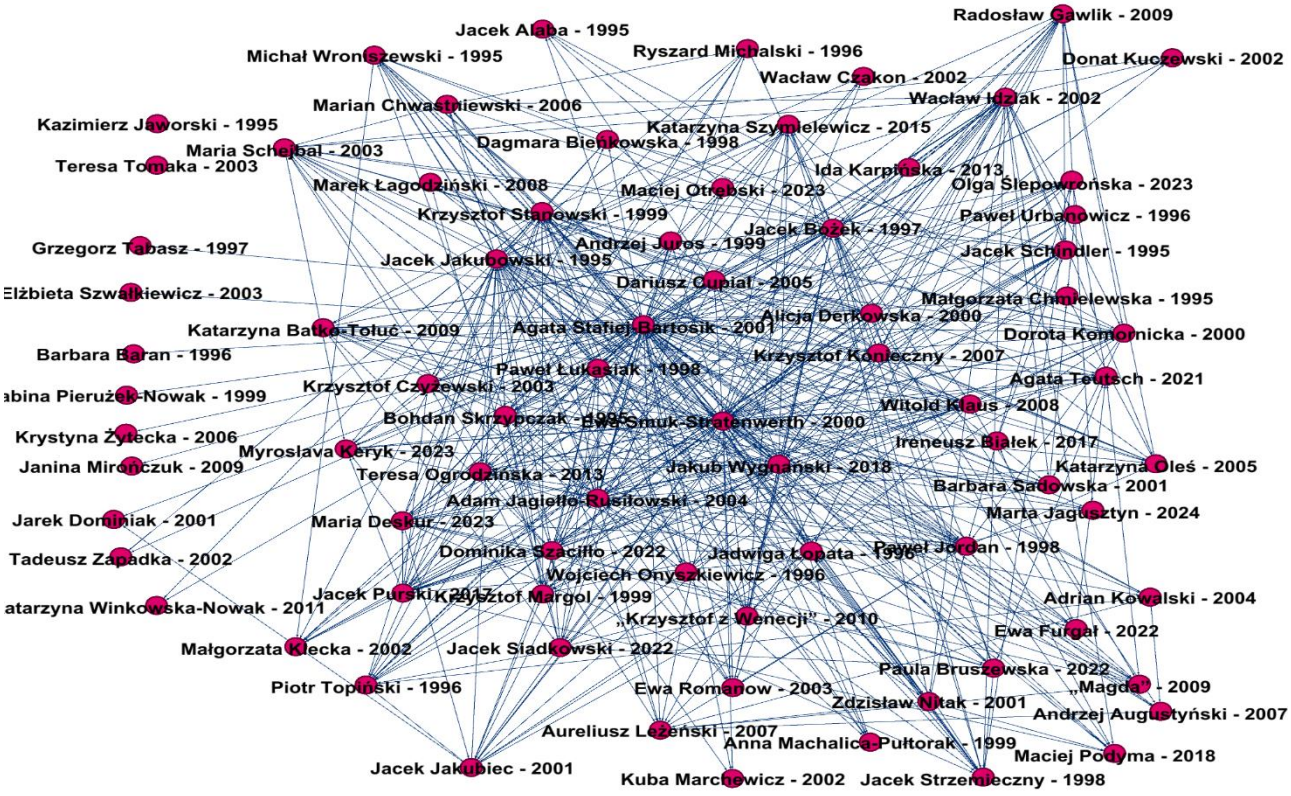

Figure 1. A connection graph, with the date of election to Ashoka visible.

Visualization of selected node characteristics is presented in Figure 2.

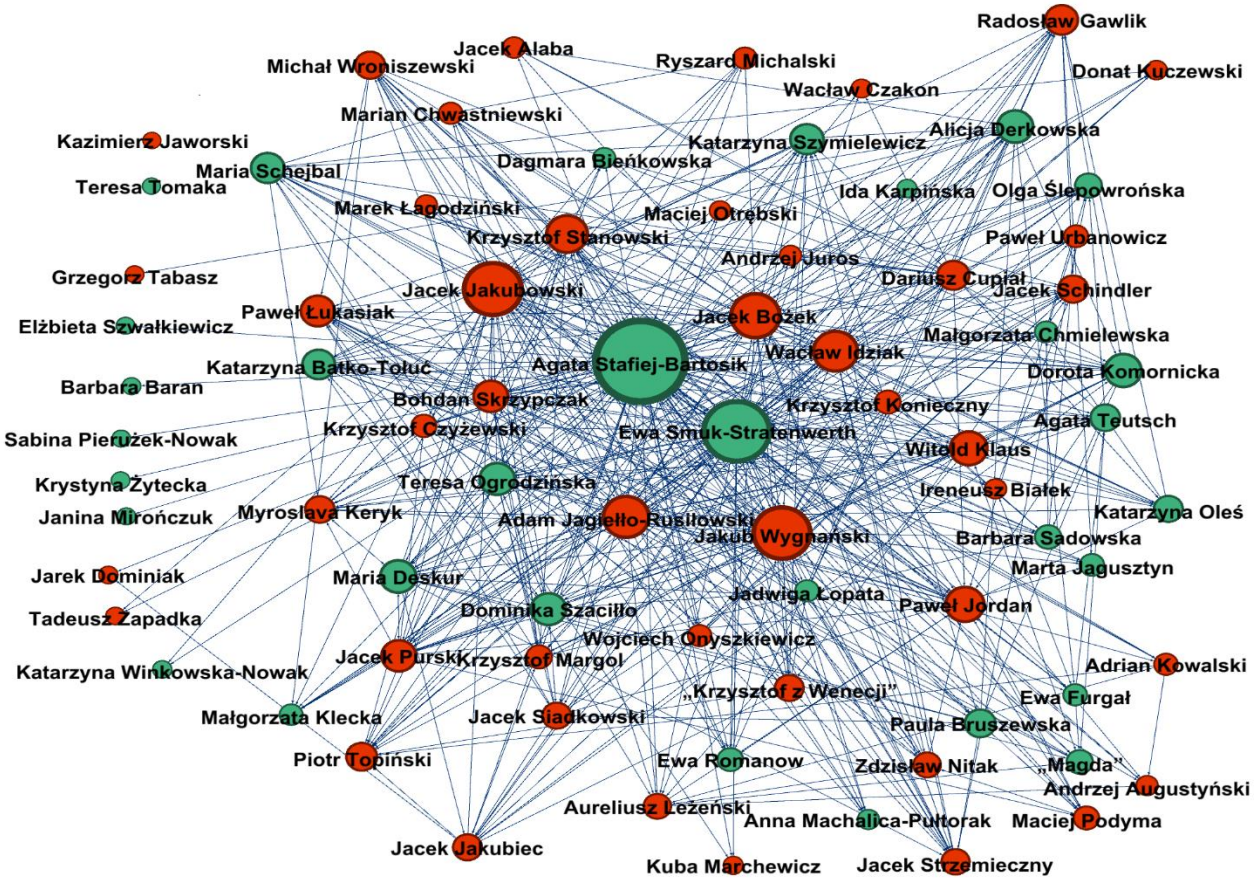

Figure 2. Connection graph with node sizes representing their degree. Red, men; green, women.

The next sociogram (Figure 3) demonstrates the most densely connected hub. It is assumed that it includes nodes with degrees between 41 and 112.

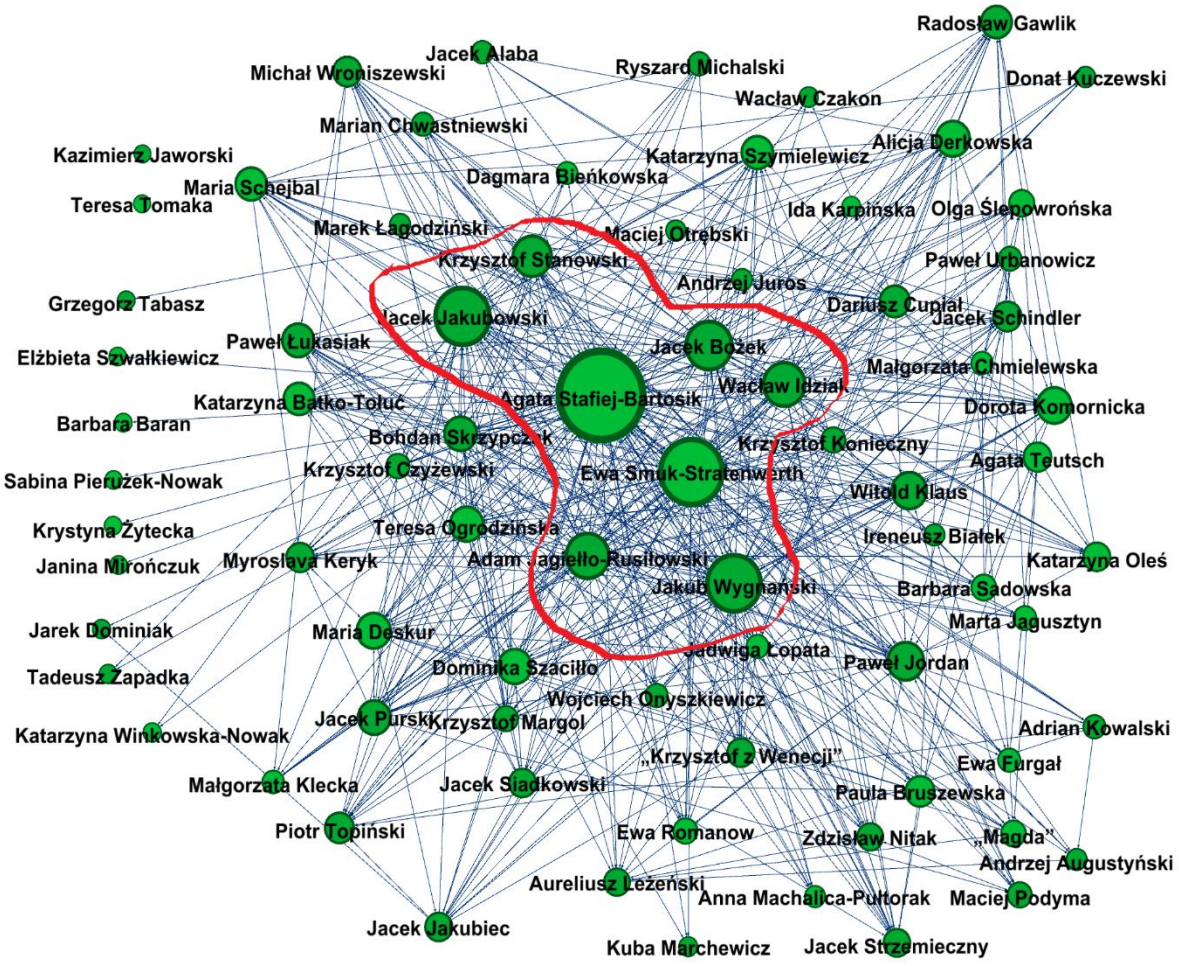

Figure 3. Densely connected hubs (degrees between 41 and 112).

Figure 4 provides a visualization of structural holes, highlighting nodes with few or no connections.

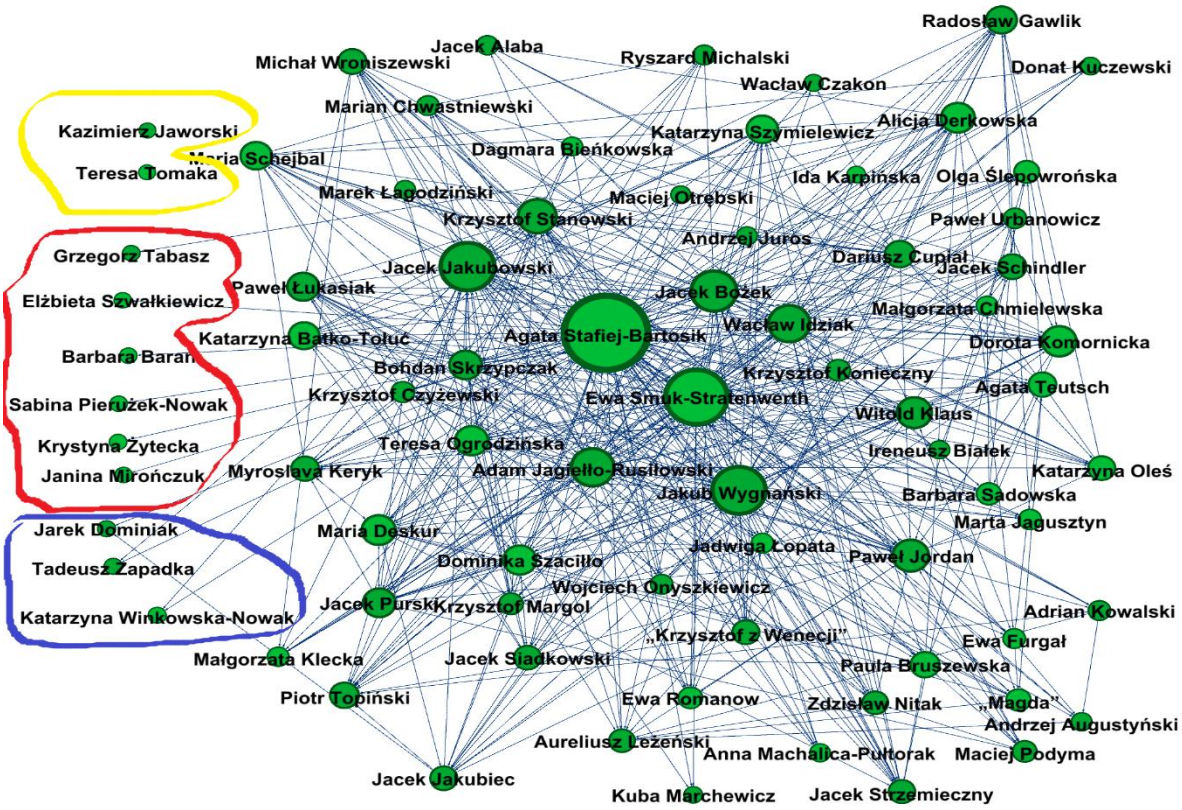

Figure 4. Structural holes. Yellow, no connections; red, one connection; blue, two connections.

Cooperation

Table 3 displays the statistics of the cooperation network.

Table 3. Measures of the cooperation network.

# of nodes	77	Most of the 77 nodes are mentioned in the results, including those who did not complete the questionnaire. Most of these unresponsive nodes are mentioned by those who did fill it out, thus they are represented as cooperation connections.
# of edges	290	The total number of cooperation connections
Average degree of all nodes	3.77	The average cooperation connectivity of all nodes in the entire network. This means that the average node has nearly 4 cooperation connections.
Network density	0.05 (5%)	The number of existing connections divided by all possible connections (how many edges there are, compared to all theoretically possible edges).
Average path length	2.44	The number of nodes that must be traversed to reach all other nodes, averaged across all possible paths; the shorter the path the better (i.e., the lower the better).
Network diameter (closeness)	5	The average shortest distance between the two most distant nodes in the network.

A graphic representation of the cooperation network is displayed in Figure 5.

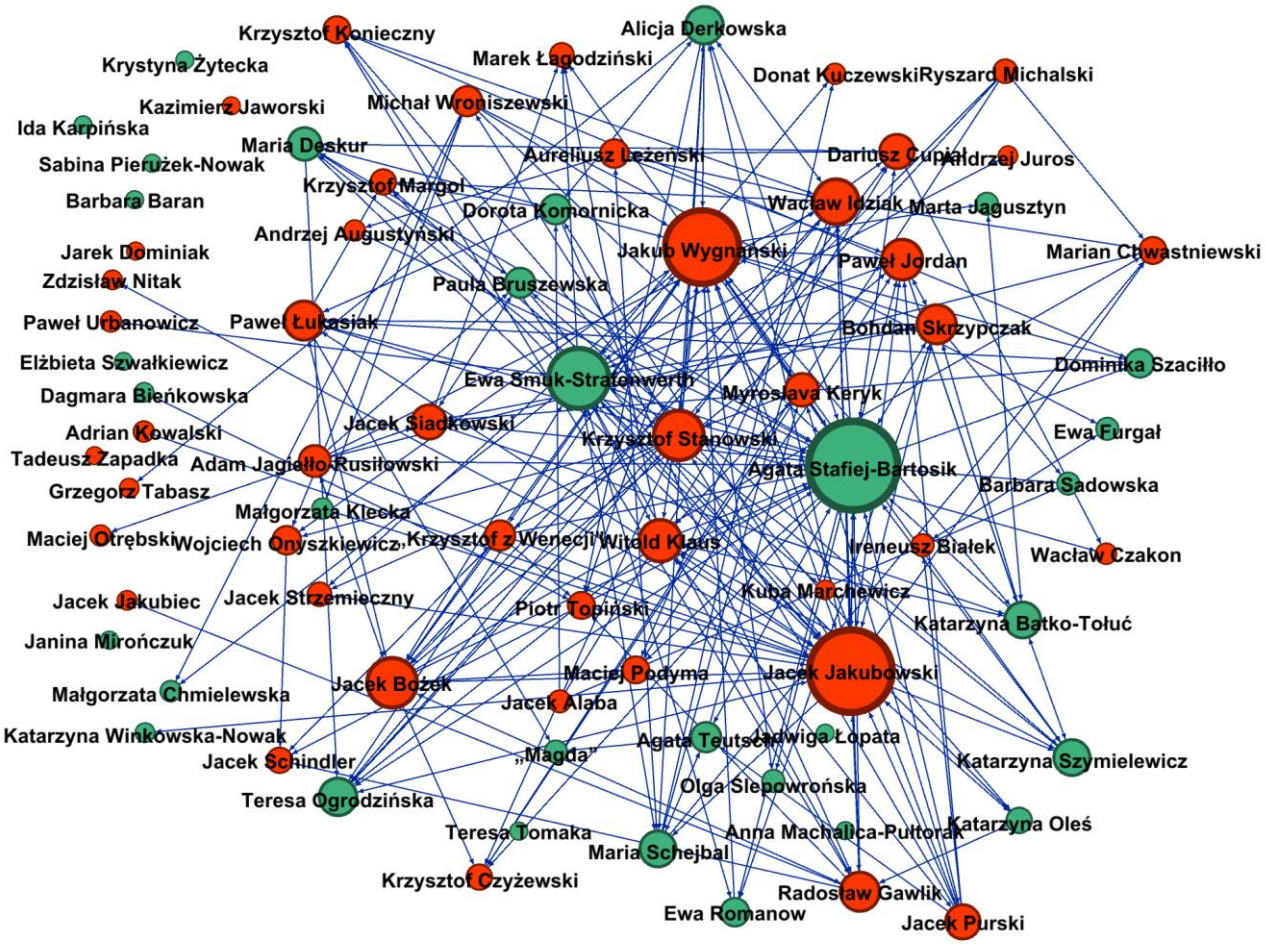

Figure 5. A cooperation network. The size of the nodes represents their degree (# of connections), and the color represents gender (red, male; green, female).

A densely connected cooperation hub is shown in Figure 6.

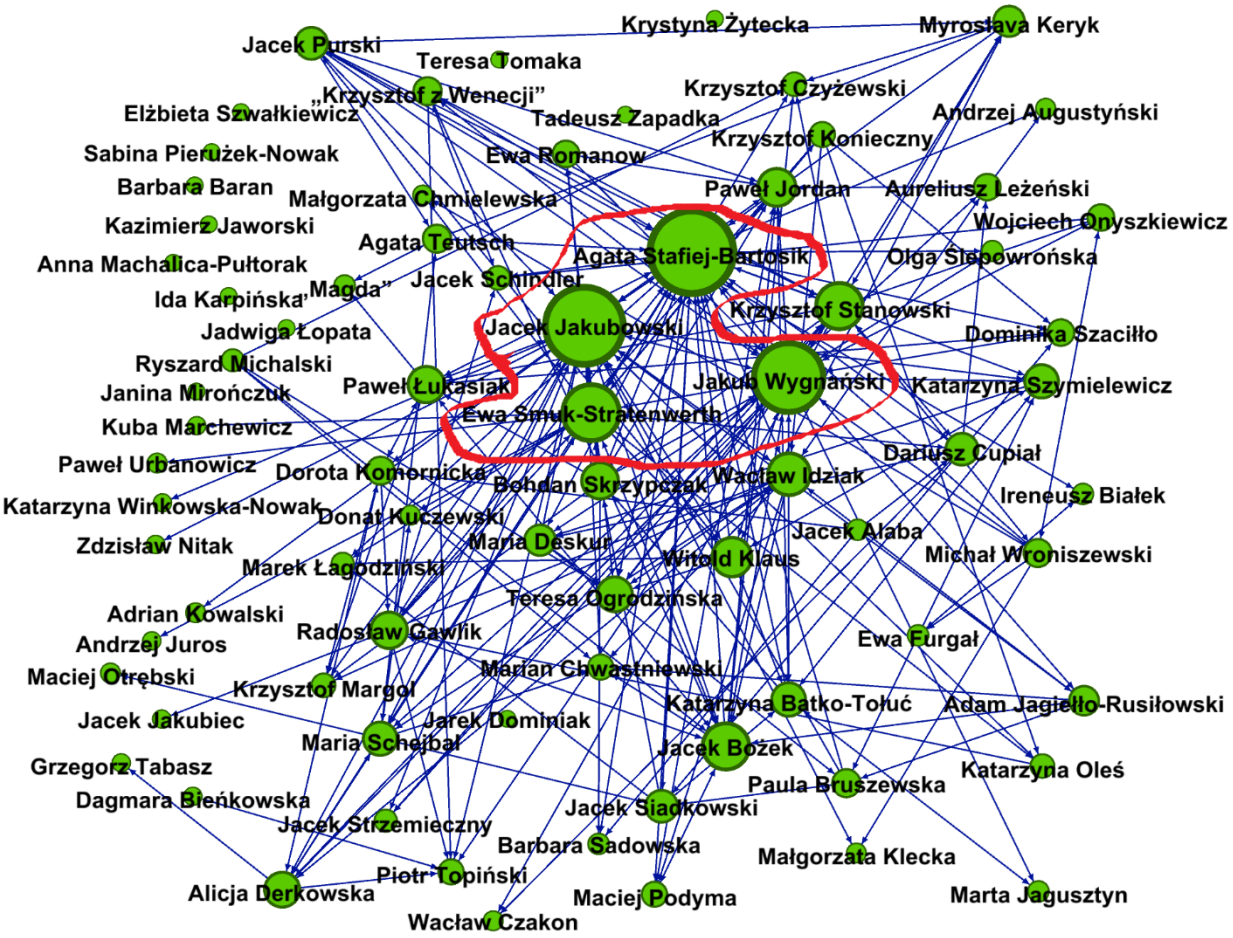

Figure 7. Cooperation hub. Degree = 28–47.

Visualization of structural holes is exhibited in Figure 7.

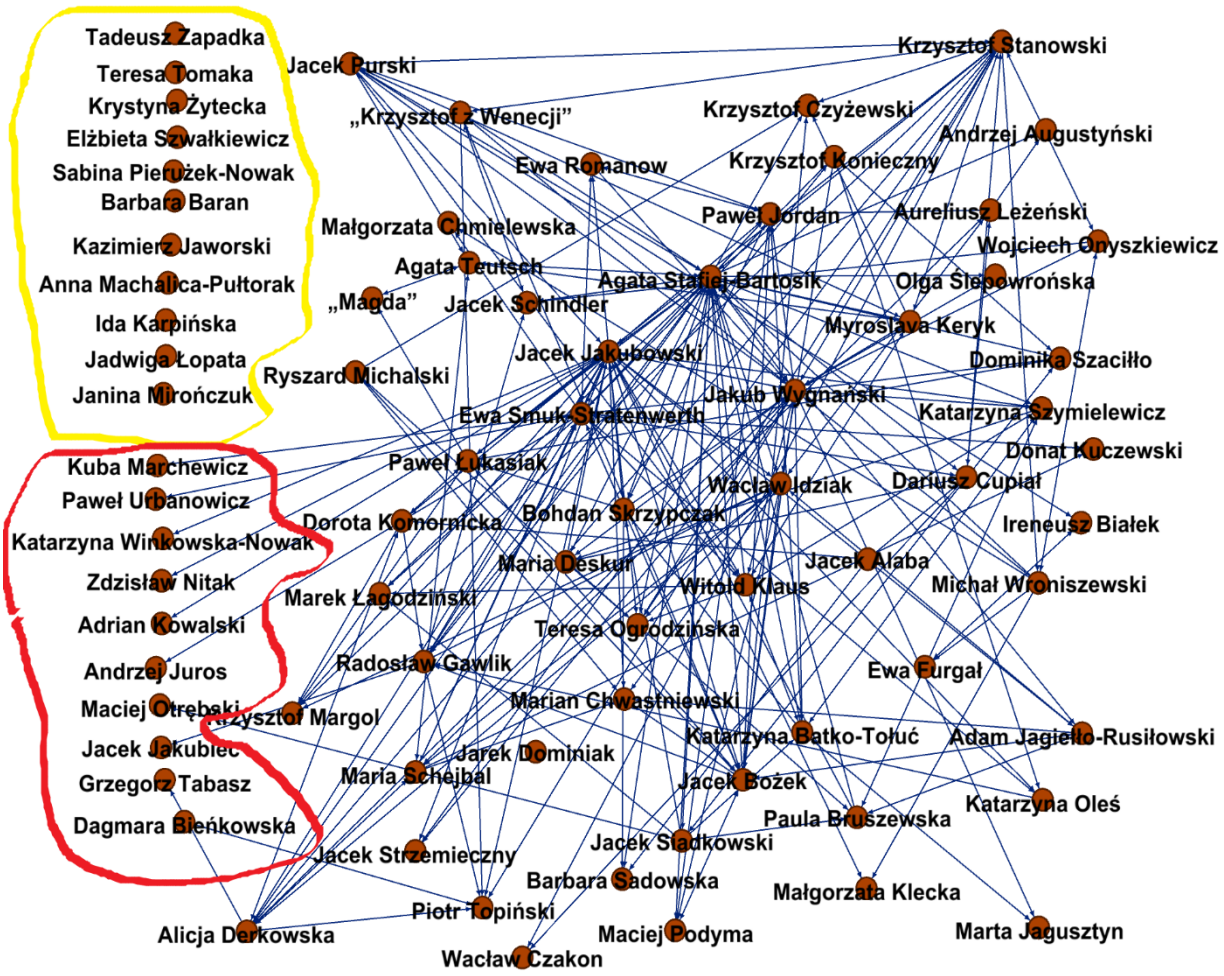

Figure 7. Structural holes of cooperation. Yellow, no connections; red, one connection.

Results Summary

This study demonstrated 683 connections between the 77 Ashoka Fellows. Each Fellow, on average, has established 8.87 connections with other Fellows. The density of the entire network is 11.7% (nearly 12% of all theoretically possible connections), and the average path length is 1.95 (all others are no more than two “jumps” away).

Moreover, it revealed 290 cooperation lines, meaning that 290 peer-to-peer projects have been run, initiated in a bottom-up way. Each node (Fellow) has established, on average, 3.77 cooperative connections, i.e., the average Fellow is involved in nearly four different projects with other Fellows.

These 290 cooperation projects add value to the organization, enriching its impact through new bottom-up ventures. The cooperation lines between Ashoka Fellows are additional levers beyond their individual projects, bringing positive changes to society.

Conclusions and Discussion

Horizontal Communication

Horizontal communication (i.e., members of different organization levels and from different departments communicating directly with each other) is seen as beneficial in many ways: This sort of interaction provides various opportunities and resources (van der Hulst,

2008). There is greater ease in problem solving, information sharing, and task coordination (Praszkier, 2018). Additionally, horizontal communication can enhance morale and serve as a means for resolving conflicts (Papa et al., 2007).

Probably the first deliberate method taking advantage of horizontal communication was Japanese Quality Circles (implemented in the 1960s), i.e., groups of regularly meeting workers (3–12 participants) from different levels, to identify, analyze, and solve work-related problems (Bocker & Overgaard, 1982). This approach appeared beneficial for organizational performance and, as such, evolved into the Kaizen method, also known as "Zero Investment Improvement," due to taking advantage of existing resources (Imai, 1986). Horizontality also augments organization members' creativity (Guthrie, 2021; Sen, 2024).

For this article, it is important to note that teamwork (i.e., peer-to-peer cooperation) is seen as one of the chief advantages of horizontal communication: Coworkers speak to, meet with, and generate ideas amongst people from different departments (Guthrie, 2021; MasterClass, 2022; Sen, 2024; Singh, 2020).

The Network Effect Hypothesis

Qualitative Depiction

Summarizing the case study of the Polish Ashoka fellowship, there seem to be several steps involved:

First step: Multiple community-building initiatives, fostering the spirit of comradeship and building the connectivity mindset. The multiplicity and diversity of events encourage free fellow-to-fellow discussions and idea exchange, fostering the connectivity mindset (see the above section "The Target Population").

Second step: The spontaneous self-igniting development of multiple peer-to-peer horizontal communication lines, visible in the SNA of the connectivity network.

Third step: Based on the intense connectivity network, there appears to be an autocatalytic development of diverse bottom-up, peer-to-peer cooperation initiatives visible in the SNA of the cooperation network.

Fourth step: New peer-to-peer initiatives add value to the primary mission of the organization, as well as to each individual participant's goals.

Quantitative Estimation of the Network Effect

As this is the first step, piloting an analysis of the intensity of network connections leading to the occurrence of multiple new cooperation lines, an initial network effect benchmark can be drawn from this study. Based on the above-mentioned connections statistics, the criteria for the occurrence of the network effect could be set as follows:

- Connectivity network participants should be connected with at least eight other participants.
- The entire network density should be higher than 11%.
- The "compactness" of the network (average path length) should be lower than two.

This, however, should be verified in future comparative studies.

Applications

The presented research provides some new reflections on the nature of horizontality and the network effect; as such, it may be a getaway for further studies.

Moreover, the theory, as well as the survey application and its results, may be beneficial both for the business sector and for social organizations and movements. It may pave the way to augmenting impact through second-order implications, i.e., through horizontal connectivity.

Finally, this study may also be advantageous for educating young social and business leaders.

Future Studies

As said, this pilot study would benefit from being compared to the analysis of other networks. Based on a larger number of SNAs, the preconditions for the network effect may be set in a more precise way.

Moreover, future studies may involve some other variables. For example, it may be interesting to see how an individual's position in the network (her/his degree, closeness, and betweenness) correlates with her/his creativity, self-reliance, or happiness (see the network-related conjectures in the "Survey" section).

Finally, longitudinal research could explore the dynamics of networks, helping to answer such questions as how some particular network parameters correlate with the growth of connectivity/cooperation over time and vice versa—when the dynamics tend to be suppressed.

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