ACCHE
Annual conference on Challenges of Contemporary Higher Education

Kopaonik, Serbia, 03-07.2.2025.

THE USE OF SOCIAL NETWORK ANALYSIS VISUALIZATION TOOLS IN TECHNICAL SCIENCES

Nenad Janjić[1] Ljiljana Ćumura[2] Branko Savić[3]

Abstract: This paper explores the application of social network analysis (SNA) visualization tools in technical sciences, highlighting its role in understanding collaboration, innovation, and industrial networks. Several tools, including AllegroGraph, Commetrix, Cytoscape, Draw.io, GraphStream, Graphviz, Gephi, JUNG, Kumu, NetDraw, Netlytic, NetMiner, NetworkX, NodeXL, PARTNERCPRM, PARTNERme, Pajek, Pollinode, Python, Statnet, SocNetV, Tulip andUCINET are reviewed to assess their capabilities and suitability for various technical applications. Using a comparative approach that integrates literature review and case studies, the paper aims to demonstrate the value of SNA tools in enhancing collaboration, information dissemination, and innovation in technical domains.

Key words: social network analysis (SNA), visualization tools, innovation, network science, mapping, graph theory, technical sciences.

1. INTRODUCTION

Social Network Analysis (SNA) has become a crucial and powerful methodology for understanding, visualizing, and interpreting complex relational data in various disciplines, including technical sciences. With the rise of interdisciplinary collaborations and the need to analyse large datasets, SNA tools have found increasing relevance in engineering, information systems, industries, technology, and project management. SNA offers a systematic approach to visualize and analyse these relationships, uncovering patterns and insights that traditional analytical methods may overlook. Social network analysis tools use network or graph theory to examine various structures, with its main components: nodes and edges. This paper explores the use of SNA visualization tools in technical sciences, focusing on their applications in fostering innovation, improving organizational efficiency, and facilitating knowledge dissemination[4]. Additionally, the authors highlight the growing importance of visual analytics in technical research and provide a comparative analysis of widely used SNA tools, helping researchers and practitioners select appropriate tools for their specific needs.

2. LITERATURE REVIEW

Social network analysis has evolved significantly over the past few decades. Wasserman and Faust [1] highlight SNA's ability to illuminate relationships within social systems, while more recent studies explore its applicability in industrial networks [2], economy [3], [4], automotive industry [5], [6], engineering community [7], etc. Cross and Parker [8] highlighted the importance of networks in organizational contexts, showing how relationships can drive innovation and efficiency. Borgatti et al. [9] discussed the relevance of network analysis in social sciences and highlighted its interdisciplinary applications, including technical and engineering contexts.Scott [10] emphasized the methodological rigor required in network analysis, which has influenced subsequent applications in technical sciences. Newman [11] provided a comprehensive introduction to network theory, which underpins the algorithms used in many SNA tools. Furthermore, Barabási[12] introduced the concept of scale-free networks, which is particularly relevant in understanding the structure of large technical networks. Blondel et al. introduced an efficient algorithm for community detection in large networks (a Belgian

[1]PhD, Professor of applied studies, Higher Education Technical School of Professional Studies, Školska 1, Novi Sad, Serbia, e-mail: janjic@vtsns.edu.rs ; https://orcid.org/0000-0003-1795-8453
[2]PhD candidate, Belgorod State Technological University named afterV.G. Shukhov,46 Kostyukova street, Belgorod, Russian Federation, e-mail: ljiljana.cumura@mail.ru ; https://orcid.org/0000-0002-9614-7618
[3]PhD, Professor of applied studies, Higher Education Technical School of Professional Studies, Školska 1, Novi Sad, Serbia, e-mail: savic@vtsns.edu.rs
[4]The idea for writing this paper arose after participating in the seminar "Tackling Complexity: Multimethod Approaches in the Social Sciences (GEPHI, SNA, Nvivo, Text Analysis, Ethnographic Field Work)", held on October 21-25, 2024, led by Dr Alexander Mesarovich, Max Weber Fellow, European University Institute.

mobile phone network of 2 million customers)usinga heuristic method based on modularity optimization (a web graph of 118 million nodes and more than one billion links) [13].

Despite significant progress in SNA methodologies, a research gap remains in applying these tools to technical project organization and engineering networks. Chinowsky and Taylor [7] highlighted the emerging approach of using networks in engineering project studies but noted the need for more empirical studies to validate theoretical models. Similarly, Khokhar [14] provided practical insights into using Gephi for network visualization but did not address its specific applications in technical sciences. SNA in technical sciences is applied to study collaboration networks, information dissemination, and system interactions. Tools such as Gephi[6], [15], and UCINET [5] have been extensively used to visualize and analyse technical networks, providing insights into connectivity and centrality measures. Basole et al. highlighted that “current practices and tools, however, have limited capabilities and do not allow for systemic exploration of alternate risk strategies”[16].They develop “a computational model of risk diffusion in global supply networks that is grounded in techniques from complex systems, network analysis, and epidemiological risk modelling.” Furthermore, Danilova, Popova and Karpova[17] presented the cluster user activity and displayed user-topic relationships on graphs in a dashboard application to monitor the changes in Russian social media’s information space during the lockdown.Boccaletti et al. [18] noted that “the first approach to capture the global properties of such systems is to model them as graphs whose nodes represent the dynamical units, and whose links stand for the interactions between them. On the one hand, scientists have to cope with structural issues, such as characterizing the topology of a complex wiring architecture, revealing the unifying principles that are at the basis of real networks, and developing models to mimic the growth of a network and reproduce its structural properties. On the other hand, many relevant questions arise when studying complex networks’ dynamics, such as learning how a large ensemble of dynamical systems that interact through a complex wiring topology can behave collectively” [18].The connections between networks’ dynamics, Grandjean [19] presented in Figure 1 and Figure 2.

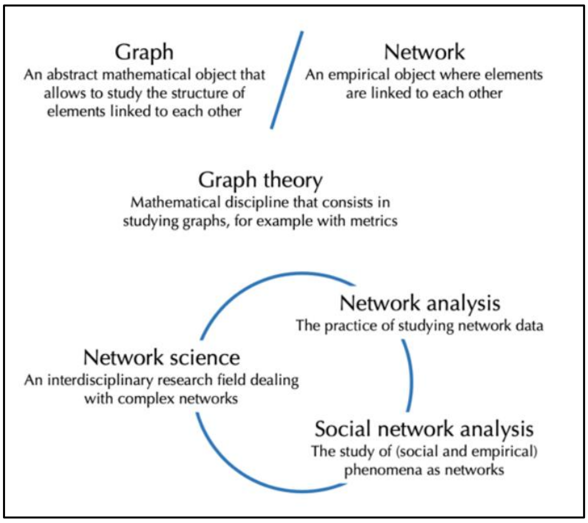

Figure 1 – Connection between graphs and SNA, Source: Grandjean [19], p. 5

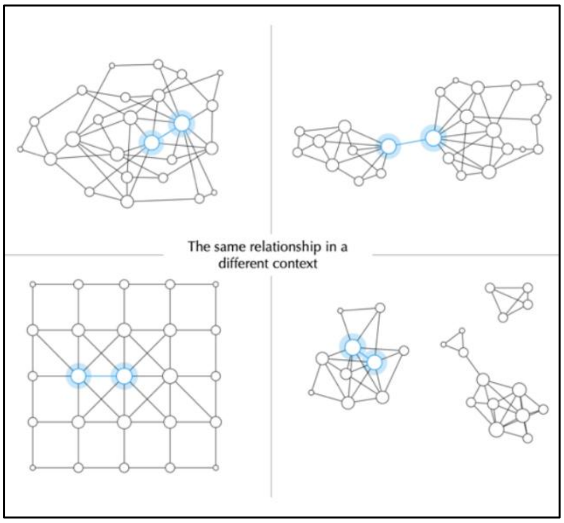

Figure 2 – The same relationships in a different context, Source: Grandjean [19], p. 2

This review indicates that while foundational work on SNA exists, there is a need for more focused studies that apply SNA tools to technical science problems. The gap in current literature can be addressed by comparing various SNA tools and demonstrating their practical utility in real-world technical applications and different context.

3. RESEARCH DESIGN & METHOD

Research Questions: What are the strengths and limitations of using SNA tools for researchand practical applications in technical fields? How can SNA tools be effectively utilized in technical sciences?

Main Goal: The primary goal of this paper is to assess the applicability of various SNA visualization tools in technical sciences by comparing their features, usability, and analytical capabilities.

Methods: A comparative approach was adopted, combining a literature review with case studies from technical fields. The selected tools were evaluated based on criteria such as ease of use, visualization capabilities, analytical features, and applicability to technical problems.

4. RESULTS

The analysis reveals that each SNA tool offers unique advantages tailored to specific research contexts. Table 1 presents a description of the SNA visualisation tools with main characteristics.

Table 1- SNA tools' basic description (in alphabet order)

Tool	Description
AllegroGraph	Graph database developed to store Resource Description Framework triples. Designed for extracting insights from highly complex data via Knowledge Graph-building solutions.
Commetrix	Designed for analyzing dynamic network change and lifecycles. The tool combines dynamic text mining, graphic visualization, and various filter algorithms.
Cytoscape	Designed for performing advanced analysis and modeling on massive datasets
Draw.io (diagrams.net)	Although not an SNA-specific tool, Draw.io is widely used for creating diagrams and flowcharts, supplementing SNA tools in technical documentation.
GraphStream	A simple tool to represent and process complex graphs. Designed for handling the graph evolution.
Graphviz	Graph Visualization Software is a free, open-source graph visualization framework. It has several main graph layout programs suitable for social network visualization.
Gephi	Widely used in technical research for visualization, exploring large datasets and identifying key nodes.
JUNG	Java Universal Network Graph Framework is designed for information visualization, knowledge discovery, and data mining.
Kumu	A robust network visualization platform for mapping systems and better understanding relationships. Ideal for understandably presenting complex technical networks.
NetDraw	A tool usually used in tandem with UCINet to visualize networks.
Netlytic	A cloud-based tool designed for analysing online networks, such as social media interactions. It has been used in studies involving online technical communities.
NetMiner	A software tool for exploratory analysis and visualization of large network data.
NetworkX	A Python library for creating and analyzing the structure and dynamics of complex networks through the massive graphs.
NodeXL	Free and open-source Network Overview Discovery Exploration for Excel is designed for smaller networks and quick analyses.
PARTNER CPRM	Designed for community network mapping. Valuable for technical projects involving stakeholder collaboration. Its focus on relationship dynamics makes it a useful tool for analysing project networks.

PARTNERme by Visible Network Labs	Designed for mapping personal networks and stakeholder engagement, making it relevant for technical consultancy projects.
Pajek	Software for analysing and visualising large networks; particularly useful in technical applications that require handling extensive datasets.
Pollinode	Tools for network analysis, both for analysing own network data and for collecting new network data.
Python	Python contains several packages relevant to social network analysis: igraph, sna sociometric analysis of networks, Networkx, and Graph-tool for manipulation and statistical analysis of graphs.
Statnet	Designed for implementing recent advances in network modeling based on Exponential family Random Graph Models (ERGM).
SocNetV	A user-friendly, free, open-source tool, designed for small to medium-sized networks. It includes basic SNA metrics and visualization options.
Tulip	A framework for analyzing and visualizing relational data. Designed for visualizing semantic networks.
UCINET	Designed for detailed network analysis in technical fields. Its comprehensive features make it suitable for both research and teaching purposes.

Analysis showed that PARTNER CPRM, for instance, excels in community partnership mapping by leveraging network science methodologies, providing customized onboarding for organizations, and offering advanced relationship mapping. However, its focus on community partnerships limits its use for broader applications. PARTNERme by Visible Network Labs focuses on personal network mapping. While user-friendly and tailored for individual use, its reliance on self-reported data limits its applicability in broader research contexts. Gephi stands out for its dynamic visualization and real-time analysis capabilities. As an open-source platform, it is accessible to a wide audience, including researchers and students. Its extensibility through plugins enhances its versatility, making it suitable for complex network visualization tasks. Nevertheless, Gephi’s user interface may pose challenges for beginners, and analysing large networks requires significant computational resources. NodeXL integrates seamlessly with Microsoft Excel, making it an ideal choice for users familiar with spreadsheet-based analysis. Its broad range of metrics, including centrality and clustering, supports detailed social network analysis. Despite its accessibility, NodeXL is platform-dependent and available only for Windows, with advanced features requiring a paid license.UCINET, known for its extensive analytical techniques, caters to advanced researchers in social network studies. Its integration with NetDraw enhances its visualization capabilities. However, the dated interface and steep learning curve can be barriers for new users. Netlytic is a cloud-based tool that specialises in social media analysis, making it valuable for marketing and communication research. Its automated data collection and analysis simplify the study of online community dynamics. However, the free version’s data processing limitations and focus on social media may restrict its broader applicability. SocNetV, designed for educational purposes, provides a user-friendly interface and essential network analysis metrics. Its versatility makes it a good starting point for students and educators. However, its visualization capabilities are relatively basic compared to more advanced tools, and documentation may be less comprehensive. Pajek is tailored for large-scale network analysis, offering robust features for handling extensive datasets. It supports academic research by providing powerful analytical tools free for non-commercial use. The complex interface and limited documentation can deter less experienced users. Pollinode excels in organisational network analysis by integrating surveys for data collection. It effectively identifies informal networks and collaboration patterns. However, its extensive feature set requires a learning period for new users and is primarily designed for organisational contexts. Kumu offers versatility in visualizing complex systems and relationships, supporting applications in systems thinking and consultancy. Its interactive visualizations enable dynamic presentations. Yet, managing large datasets can become complex, and it offers fewer analytical metrics than dedicated SNA tools. Draw.io provides a straightforward solution for creating network diagrams and flowcharts. Its simplicity and accessibility make it suitable for essential/basic documentation but lacks advanced SNA analytical features.

5. DISCUSSION

The comparative analysis highlights that different SNA tools cater to varied needs in technical sciences, each offering distinct advantages and facing unique challenges. The findings from the results section emphasize that tools like Gephi, UCINET, and Pajek are particularly effective for handling large datasets and performing in-depth analyses, aligning with the insights of Wasserman and Faust [1] on the importance of robust methodological frameworks in network analysis.Tools such as PARTNER CPRM and Pollinode demonstrate the growing emphasis on community and organizational network mapping, reflecting Cross and Parker's [8] observation that understanding relationship dynamics is critical for fostering collaboration. Meanwhile, the user-friendly design of NodeXLand SocNetV underscores the need for accessible tools that can bridge the gap between technical expertise and practical application [5], a gap noted by Scott [10] in his discussion on methodological inclusivity. For large-scale technical projects, tools like Gephi and Pajek are recommended due to their scalability and advanced features. For smaller networks and educational purposes, NodeXL and SocNetV provide an accessible entry point. Additionally, combining multiple tools, such as Draw.io for documentation and Gephi for analysis, can enhance research workflows.

Despite the advancements in SNA tools, challenges remain. For instance, the steep learning curve associated with tools like UCINET and Pajek highlights the need for better user support and documentation, as emphasized by Khokhar [14] in his practical guide to using Gephi. Furthermore, while cloud-based platforms like Netlytic offer ease of access, their data processing limitations indicate the need for scalable solutions that can efficiently handle larger datasets. The article by Rasskazov et al. [20] considers the following doubts about the use of UCINET: "the definition of the diagnostic process in relation to social networking organization; the possibility of social networking quantitative analysis; the illustration of how to use the theory of social capital as a sociological basis for the social networks diagnostics in the small business and the calculations of illustrative indicators and real networks in the case of a small business organization in Russia."

Another critical point of discussion is the integration of multiple tools to enhance analysis. As Blondel et al. [13] noted, community detection algorithms can be more effective when combined with visualization tools that provide intuitive insights into network structures. This approach can be particularly beneficial in technical sciences, where complex systems often require multi-faceted analysis.Overall, the discussion highlights that while significant progress has been made in developing SNA tools [21], [22], further work is needed to address existing limitations and enhance their applicability in technical domains. Future research should focus on standardizing methodologies and improving tool interoperability to provide more comprehensive solutions for technical network analysis.

6. CONCLUSION

This paper underscores the value of SNA visualization tools in technical sciences, demonstrating their potential to improve research outcomes and decision-making processes. It is recommended that researchers select tools based on their specific project requirements, considering factors such as network size, complexity, and desired outputs.

7. REFERENCES

[1] Wasserman, S.; Faust, K.: *Social Network Analysis: Methods and Applications*, Cambridge University Press, 1994.
[2] Freeman, L. C.: *The Development of Social Network Analysis: A Study in the Sociology of Science*, ΣPEmpirical Press, Vancouver, 2010.
[3] Engel, J.;Nardo, M.;Rancan, M.: *Network Analysis for Economics and Finance: An Application to Firm Ownership*, pp. 331-355, 2021 , https://doi.org/10.1007/978-3-030-66891-4_14.

[4] Ricken, B.:*Cross/Parker (2004): The Hidden Power of Social Networks*, pp. 133-136, 2019, https://doi.org/10.1007/978-3-658-21742-6_31.
[5] Squarsado Ferreira, A.;Sacomano Neto, M.; Eduardo Alvarez Candido, S.; Mendonça Ferratti, G.: Network Centrality and Performance: Effects in the Automotive Industry, in *Review of Business Management* 23 (4): 677-695, 2021, https://doi.org/10.7819/rbgn.v23i4.4132.
[6] SacomanoNeto M.;Carmo M. J. et al.: Corporate ownership network in the automobile industry: Owners, shareholders and passive investment funds, in *Research in Globalization* 2 (3)100016: 1-12, 2020, https://doi.org/10.1016/j.resglo.2020.100016.
[7] Chinowsky, P.; Taylor, J. E.: *Networks in Engineering: An Emerging Approach to Project Organization Studies*, in Engineering Project Organization Journal 2: 15-26, 2012. https://doi.org/10.1080/21573727.2011.635647.
[8] Cross, R.; Parker, A.: *The Hidden Power of Social Networks: Understanding How Work Really Gets Done in Organizations*, Harvard Business Review Press, 2004.
[9] Borgatti, S. P. et al.: Network Analysis in the Social Sciences, in *Science* 323(5916):892-895, 2009, https://doi.org/10.1126/science.1165821.
[10] Scott, J.:*Social Network Analysis: A Handbook*, SAGE Publications, 2000.
[11] Newman, M. E. J.:*Networks: An Introduction*, Oxford University Press, 2010.
[12] Barabási, A.-L.:*Linked: The New Science of Networks*, Perseus Books Group, 2002.
[13] Blondel, V. D. et al.: *Fast Unfolding of Communities in Large Networks*, in Journal of Statistical Mechanics: Theory and Experiment P10008, 2008, https://doi.org/10.1088/1742-5468/2008/10/P10008.
[14] Khokhar, D. A.: *Gephi Cookbook: Over 90 Hands-On Recipes to Master the Art of Network Analysis and Visualization with Gephi*, Packt Publishing, 2015.
[15] Bastian M.;Heymann S.;Jacomy M.:Gephi: an open source software for exploring and manipulating networks, in *International AAAI Conference on Weblogs and Social Media*, 2009, https://doi.org/10.13140/2.1.1341.1520.
[16] Basole, R.et al.: Computational Analysis and Visualization of Global Supply Network Risks, in *IEEE Transactions on Industrial Informatics* 12(3): 1206-1213, 2015,https://doi.org/10.1109/TII.2016.2549268.
[17]Danilova, V.; Popova, S.;Karpova, V.: *A Pipeline for Graph-Based Monitoring of the Changes in the Information Space of Russian Social Media during the Lockdown*, 2021, https://doi.org/10.48550/arXiv.2110.13626.
[18] Boccaletti, S. et al.:Complex networks: Structure and dynamics, in *Physics Reports*, 424: 175-308, 2006,https://doi.org/10.1016/j.physrep.2005.10.009.
[19]Grandjean.M.: Introduction to Social Network Analysis: Basics and Historical Specificities,in *Proceeding Book*, *HNR+ResHist Conference*, University of Lausanne, 2021, https://doi.org/10.5281/zenodo.5083035.
[20] Rasskazov, S. et al.: *Social network analysis as an organizational diagnostic tool: The case of small business in Russia*, 6, pp. 170-176, 2016.
[21] https://visiblenetworklabs.com/resource-hub, December 2024
[22] https://www.rankred.com/free-social-network-analysis-tools, January 2025