International Journal of Production Management and Engineering

http://dx.doi.org/10.4995/ijpme.2016.4425

Received 2015-12-10 Accepted: 2015-12-14

Social network analysis and supply chain management

Raúl Rodriguez-Rodriguez* and Ramona D. Leon

Research centre on Production Management and Engigeering, Universitat Politècnica de València, Cno. de Vera s/n, 46022 Valencia (España).

* *raurodro@upvnet.upv.es*

Abstract: This paper deals with social network analysis and how it could be integrated within supply chain management from a decision-making point of view. Even though the benefits of using social analysis have are widely accepted at both academic and industry/services context, there is still a lack of solid frameworks that allow decision-makers to connect the usage and obtained results of social network analysis – mainly both information and knowledge flows and derived results- with supply chain management objectives and goals. This paper gives an overview of social network analysis, the main social network analysis metrics, supply chain performance and, finally, it identifies how future frameworks could close the gap and link the results of social network analysis with the supply chain management decision-making processes.

Key words: Social network analysis, Supply chain management, Metrics.

1. Introduction

It is currently widely accepted that the global economy has drifted and it is more and more ICT-supported than ever. Many sectors are dominated by organisations that represent this digital breakdown and fully rely on ICT advances to make a difference: Skype with no telecommunication infrastructure, Facebook with no content creation, Airbnb (world's accommodation leader) with no property owned etc. This is possible due to the fact that linking people, services and products together as well as interconnect them via information and knowledge exchange is the differentiate point nowadays. The advent of ICT shapes the organisations from inside out; it affects employees' productivity and firm's capacity of innovating (Molina-Castillo *et al.*, 2012) and at the same time, it fosters the relationship between the company and its customers (Gunawan and Huarng, 2015). In this way, organisations have available different tools in order to support and carry out these information and knowledge exchange processes. One of the most famous one is through online social networks e.g. Facebook or Twitter. However, these are open networks and organisations usually use them to communicate with their final customers instead of with the actors upstream the supply chain, namely with their suppliers. An alternative to this are the called private online social networks, which are accessed only by invitation and represent an optimal opportunity for organisations to build up a social network with their supply chain partners to foster the information and knowledge interchange. Once they have set up the social network and it has been working for a while, the application of social network analysis will outcome important additional information to make decisions.

However, it is possible to affirm that decision-makers do not have yet tools, mechanisms or frameworks that help them out to make decisions regarding how social network analysis is affecting to supply chain management and, extensively, how supply chain both as a whole and from its individual members point of view, can be linked together under an integrative approach.

This paper tackles this line of research, and it is structured as follows: The next section presents a brief literature review on i) social network analysis; ii) social network analysis metrics; iii) supply chain measurement. Emerging from this point, the main advantages of using social network analysis at the supply chain level as well as some specific lines where both social network analysis and supply chain management could be brought together are then presented. Finally, the main conclusions are highlighted.

2. Brief literature review

2.1. Social network analysis

Social network analysis has its roots in the work of Kurt Lewin (1936) who combined the abstract character of mathematics with the subjective/ interpretative character of sociology, and put the bases of the mathematical based field theory, the predecessor of the graph theory. Both findings contribute to the development of what is called today "sociometry" and provide the necessary context for analysing, measuring and understanding relationship's value.

Against this framework, a social network is defined as set of relationships developed among the members of a group. From an abstract perspective, a social network can be a representation of series of nodes and lines in which the nodes describe an individual, a team, an organization, a community or a country and the lines emphasize a relation that has been established between two nodes, based on preferences or necessity (Sandru, 2012). From a subjective approach, a social network describes the information, tacit and explicit knowledge that flows within a group of people; each node represents an individual who can act as a knowledge holder (transmitting emotions, values, ideas, experiences, advice, stories, best practices etc. to the others) or as a knowledge receiver (interacting with some of the others members in order to receive answers to his/her current or potential problems). Nevertheless, both approaches highlight a mathematical graph based on a binary interaction matrix; no matter the actors' nature, the relationships are usually encoded based on a binary code where 1 symbolizes the existence of interaction between two members and 0 reflects its absence.

Within the social network theories, social network analysis appears as a branch of mathematical sociology, capable of evaluating structural positions and characteristics at both node and network level. However, it can be used for both exploratory and confirmatory issues. On the one hand, in line with a confirmatory approach, social network analysis allows testing hypothesis by converting the subjective nature of relationships into abstract parameters and probabilities. It provides the necessary framework for testing hypothesis regarding networks' and groups' means, densities, correlations and regression and it also facilitates the prediction of future relationships (Hanneman and Riddle, 2005).

On the other hand, in line with the exploratory approach, it facilitates the visualization and exploration of nodes' and networks' characteristics. At the node level, various analysis may be conducted in order to emphasize individuals' position and characteristics (Zhu *et al.,* 2010; Hu, 2013); their importance within the network is reflected based on degree, betweenness and closeness centrality, reachability and connectivity while their preferences are highlighted through the homophily analysis. At the network level, several analysis can be developed in order to bring forward networks characteristics (Gunawan and Huarng, 2015; Lin and Lo, 2015); its potential is emphasized based on networks' density, its diversity is reflected based on clustering analysis, structural and automorphic equivalence, while its efficiency is brought forward Krackhardt GDT analysis. The SNA measures that are usually applied are presented further.

2.2. Social network analysis metrics

Through the application of social network analysis techniques, a graphical approach of the main relationships among and between the members of such a social network is first taken into account to make decisions. However, there is much more information when looking at the metrics that these analysis techniques output. (Turetken and Sharda, 2007) state that the three most used social network analysis metrics are: degree centrality, degree of intermediation (Betweenness centrality) and proximity (closeness). These three metrics are further developed next.

The degree centrality is the number of direct ties that an actor (or node) possesses; for instance, how many other nodes are directly connected. This metric indicates who is the most connected member in a group. Then, a member with a high degree has got many connections to other network members, carrying out hub tasks within the network. This implies that a member with a high degree has got a high degree to influence other members. Then, organisations that precisely identify who the hub members are possess important additional information when trying to disseminate both information and knowledge within the network. Additionally, when looking at inter-organisational contexts such a hub identification process will provide, in return, a key and valuable contact point with external supply chain companies.

Figure 1 shows an example of degree centrality where big squares mean a high degree and the small

squares a low degree. Then, it can be seen that the user U126 has got the highest degree centrality value whereas that other users located at the margins of the network such as U89, U98 or U127 has got the lowest level of degree centrality.

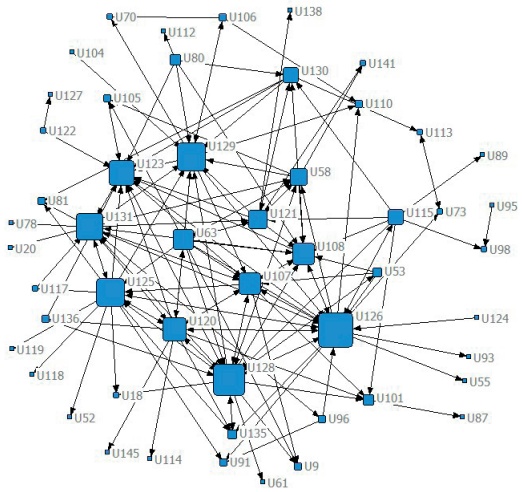

Figure 1. Example of degree centrality.

The degree of intermediation shows how often a node appears in the shortest section that connects two others. In other words, it indicates when a member plays the role of intermediary between two other members that do not keep any relationship within the network. Then, it is necessary to differentiate when these two actors that do not keep any relationships with each other: a) keep relationships with other members of the network; b) does not keep any other relationship with other members of the network, only the only kept through the intermediary. In the former case, the removal of the intermediary member is not as dramatic as in the latter one. Removal of intermediary members, carried out by organisations by any reason, when they are the only link for two isolated members will lead to a knowledge sharing loss. These intermediary members of isolated members should be the last ones to leave the network, therefore actions to foster their presence and participation should be carried out and monitored.

Figure 2 shows an example of degree of intermediation, where the big squares mean a high degree and the small squares a low degree. Then, it can be seen that the user U126 has got the highest degree of intermediation value whereas that other users located at the margins of the network such as U113 or U104 has got the lowest level of degree of intermediation.

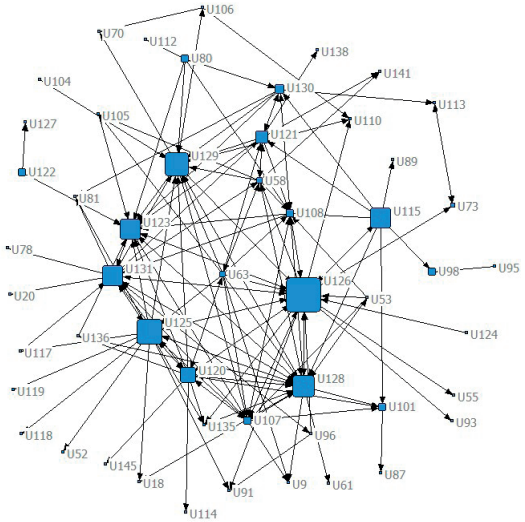

Figure 2. Example of Betweenness centrality.

Finally, the closeness or proximity metric indicates how close is a node from the rest of the network. It represents the ability of a member to reach others within the network.

Figure 3 shows an example of closeness, where the circles mean a high degree of closeness and the squares show a low level. Looking at both the incoming and outcoming arrows, it is possible to observe that users U126, U108 and U128 are the ones with a highest degree of closeness within the network.

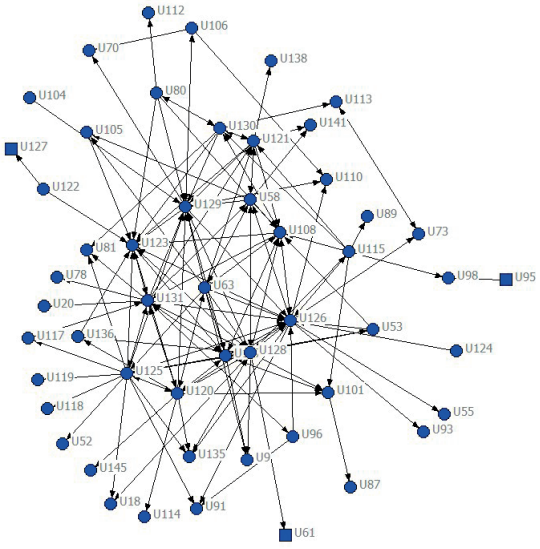

Figure 3. Example of closeness.

In any case, it is necessary to take into account that other metrics can be obtained when applying

social network analysis. These metrics are mainly related to contingency, hily, strength, heterogeneity and network density. Additionally, it is possible to develop knowledge flows forecasting by applying the Holland and Leinhardt's P1 Model (1981). These additional metrics have not been so popular within the literature and further attention should be put on their application to situations as the one presented in this paper.

2.3. Supply chain measurement

When looking at the supply chain management context aiming to establish how to measure its results and performance, many frameworks have been developed in the last years. Starting with the plane application of the well-known Balanced Scorecard (Kaplan and Norton, 1992) to other most sophisticated approaches.

To mention some recent balanced-scorecard works, Chang *et al.* (2013) developed a supply chain performance measurement system that integrates R&D activities as well as marketing policies; both Tajbakhsh and Hassini (2015) and Shafiee *et al.* (2014) developed a supply chain performance evaluation system based on the combined use of both data envelopment analysis and balanced scorecard.

Regarding supplier evaluation and selection, Heidarzade *et al.* (2016) developed a clustering method based on fuzzy logic, and Bruno *et al.* (2016) present a framework where they several combined supplier selection methodologies in a multi-stakeholder environment.

On the other hand, there have been also some supply chain performance measurement frameworks to measure the impact of collaboration over performance. Then, Verdecho *et al.* (2012) applied the Analytic Network Process to identify the main collaborative factors and to evaluate how collaboration practices affect to performance; Kee-Hung *et al.* (2015) presented a work regarding how environmental information sharing affects to supply chain partners and performance.

However, when it comes to link together supply chain management and social network analysis there is a gap from a researching point of view. In other words, if members of a supply chain share and develop both information and knowledge for a certain time period, they will not have available any solid framework to help them out to interpret and project their findings, at the social network context, towards the supply chain one. The latter will ask to quantify how certain actions of, for instance, knowledge sharing within the social network will help to achieve shorter cycle times. These two-sided intrinsically linked decision-making contexts should be further studied, and solid and effective frameworks developed. In the next point, we provide some insights that could be taken when trying to accomplish this task.

3. Social network analysis and supply chain management

Derived from the previous point, it is possible to highlight the main advantages of maintaining a social network and develop associated analysis through its metrics. Such advantages are mainly: fostering innovation capabilities, increment of the task orientation level and facilitating of both internal and external communication. These three are next further developed.

The implementation and use of suppliers' social network enhances the innovation capability of each member and the supply chain as a whole. First of all, it ensures the creation of a shared vision and it increases members' cohesion. Based on this, networks leaders act as distributors, disseminating the image of what they are as a supply chain and what do they aim to be. As a consequence, the members understand what happens with their products once they leave their factory, what is the role they play into the big system (the supply chain) and with which organisations they should cooperate more in order to improve their strengths and diminish their vulnerabilities.

Second of all, it increases the level of task orientation. Once each firm knows where does it stands within the supply chain, it can adapt its internal processes and structures so that it increases its performance and also the supply chain performance. At this level process innovation may appear in order to improve decision-making, collaboration between several departments or teams etc.

Third of all, it facilitates internal and external communication and knowledge sharing. At the internal level, it supports organizational learning and it facilitates the process of intergenerational learning since knowledge is shared among the social network. Besides strengthening the relationships

between employees, it also supports the processes of human resources evaluation (especially, those related to skills and abilities evaluation), and it offers the necessary framework for designing internal knowledge maps (which shows who knows what).

Therefore, it is widely accepted that social network analysis brings organizational competitive advantages. The remaining question is: to what extent? The creation, implementation and maintenance of a social network within a supply chain will lead, if properly managed to, among others, the advantages above highlighted. But the question is: how is paying-off to create and maintain a social network? Further, to what extend is such a social network contributing to reach specific supply chain objectives?

Up to now there are not any solid/integral framework available to respond these questions. Some possibilities are:

- To subjectively quantify the impact of social network analysis over the supply chain's results. This could be done applying subjective techniques such as questionnaires, surveys, multi-criteria decision-aid techniques, etc. The main advantage of this approach is that it does not need to wait until historical data is available. However, its main disadvantage lies in its intrinsic subjectively, as decision-makers will rely on subjective judgements instead on real data evolution.

- To objectively quantify the impact of social network analysis over the supply chain result's. This approach will need from real data from different metrics: the ones from the social network analysis –mainly the previously presented– and from the supply chain –metrics regarding operations, finance, customer, etc.–, applying then statistical techniques to find out whether there is a relationships between these set of metrics. In other words, to identify whether the social network via its metrics lead to a change – either positive or negative- on the supply chain metrics. The main advantage of this approach is that it does not rely on subjective judgement but on real data. The main disadvantage is that it requires more time for collecting the data and that the statistical techniques to be applied will be, surely, more complicated than the ones applied in the subjective approach.

Any of these two approaches are valid and could be considered as a first step for presenting a solid framework for analysing whether and to what extent social network analysis is affecting to supply chain management.

4. Conclusions

In today's world, it is widely accepted that ICT support greatly organizational decision-making processes, specially the interchange of both information and knowledge at both intra and inter-organisational contexts. One of the most recent tools to carry out such a interchange is social networks, being specially indicated for organizations closed social networks. By applying social network analysis, decision-makers has got available a set of metrics from which they can get to know who the key users, from a knowledge interchange, creation and absorption point of view, are. However, there is a lack of research when coming to connect the results obtained from social network analysis with the supply chain side. Works that either subjectively or objectively carry out such a connection are needed, as they will allow to organisations to identify how and to what extent social network analysis and practices are affecting to supply chain management.

Acknowledgements

"The research reported in this paper is supported by the European Commission for the project "Engaging in Knowledge Networking via an interactive 3D social Supplier Network (KNOWNET)" (FP7-PEOPLE-2013-IAPP 324408)".

References

Bruno, G., Esposito, E., Genovese, A., Simpson, M. (2016). Applying supplier selection methodologies in a multi-stakeholder environment: A case study and a critical assessment. *Expert Systems with Applications*, 43: 271-285. doi:10.1016/j.eswa.2015.07.016

Chan, F.T., Nayak, A., Raj, R., Chong, A.Y.L., Manoj, T. (2013). An innovative supply chain performance measurement system incorporating research and development (R&D) and marketing policy. *Computers & Industrial Engineering*, 69: 64-70. doi:10.1016/j.cie.2013.12.015

Gunawan, D.D., Huarng, K.H. (2015). Viral effects of social network and media on consumers´ purchase intention. *Journal of Business Research*, 68(11): 2237-2241. doi:10.1016/j.jbusres.2015.06.004

Hanneman, R.A., Riddle, M. (2005). *Introduction to social network methods*. Riverside, CA: University of California, Riverside.

Heidarzade, A., Mahdavi, I., Mahdavi-Amiri, N. (2016). Supplier selection using a clustering method based on a new distance for interval type-2 fuzzy sets: A case study. *Applied Soft Computing*, 38: 213-231. doi:10.1016/j.asoc.2015.09.029

Holland, P., Leinhardt, J. (1981). An Exponential Family of Probability Distributions for Directed Graphs. *Journal of the American Statistical Association*, 76(373): 33-50. doi:10.1080/01621459.1981.10477598

Hu, Y. (2013). Hyperlinked actors in the global knowledge communities and diffusion of innovation tools in nascent industrial field. *Technovation*, 33(2-3): 38-49. doi:10.1016/j.technovation.2012.10.001

Kaplan, R.S., Norton, D.P. (1992). The balanced scorecard. Measures that drive performance. *Harvard Business Review*, 70(1): 71-9.

Kee-Hung, L., Wong, W.Y., Lee Lam, S. (2015). Sharing environmental management information with supply chain partners and the performance contingencies on environmental munificence. *International Journal of Production Economics*, 164: 445-453. doi:10.1016/j.ijpe.2014.12.009

Lewin, K. (1936) *Principles of Topological Psychology*. Martino Fine Books. doi:10.1037/10019-000

Sandru, C. (2012). Epistemic and Methodological aspects of Network Analysis. *Bulletin of the Transilvania University of Braşov*, 3: 63-74.

Lin, S.W., Lo, L.Y.S. (2015). Mechanisms to motivate knowledge sharing: integrating the reward systems and social network perspectives. *Journal of Knowledge Management*, 19(2): 212-235. doi:10.1108/JKM-05-2014-0209

Molina-Castillo, F.J., Lopez-Nicolas, C., Soto-Acosta, P. (2012). Interaction effects of media and message on perceived complexity, risk and trust of innovative products. *European Management Journal*, 30(6): 577–587. doi:10.1016/j.emj.2012.07.005

Shafiee, M., Lotfi, F.H., Saleh, H. (2014). Supply chain performance evaluation with data envelopment analysis and balanced scorecard approach. *Applied Mathematical Modelling*, 38(21-22): 5092-5112. doi:10.1016/j.apm.2014.03.023

Tajbakhsh, A., Hassini, E. (2015). Data envelopment analysis approach to evaluate sustainability in supply chain networks. *Journal of Cleaner Production*, 105: 74-85. doi:10.1016/j.jclepro.2014.07.054

Turetken, O., Sharda, R. (2007). Visualization of web spaces: state of the art and future directions. *Data Base*, 38(3): 51-81. doi:10.1145/1278253.1278260

Verdecho, M.J., Alfaro-Saiz, J.J., Rodriguez-Rodriguez, R., Ortiz-Bas, A. (2012). A multi-criteria approach for managing inter-enterprise collaborative relationships. *Omega*, 40(3): 249-263. doi:10.1016/j.omega.2011.07.004

Zhu, B., Watts, S., Chen, H. (2010). Visualizing social network concepts. *Decision Support Systems*, 49(2): 151-161. doi:10.1016/j.dss.2010.02.001

