Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 221 (2023) 49–56

Procedia Computer Science

www.elsevier.com/locate/procedia

10th International Conference on Information Technology and Quantitative Management

The guidance of opinion leader on followers' opinions--based on opinion similarity and closeness perspective

Jia Chen[a*], Youyuan Li[a], Wei Sha[a], Yisong, Feng[b]

[a]*School of Business Administration, Faculty of Business Administration, Southwestern University of Finance and Economics of China, Chengdu, 611130, China*

[b]*Financial Innovation Editorial Office, Southwestern University of Finance and Economics, Chengdu, 611130, China*

Abstract

With the rapid development of the Internet technology, a large number of opinion leaders have emerged on social media platforms, affecting users' purchase decision-making behavior. opinion leaders of social network have advantages on users ' decision -making process, and can guide users' opinion in a dynamics process. Based on opinion dynamics, this paper introduces the bounded confidence model of Hegselmann-Krause (HK) model, and improves the model with introducing the opinion similarity and closeness. Using simulation experiments to describe the dynamics process of the impact of opinion leaders on followers. The experimental results show that when the opinion of opinion leaders and followers are similar and closely high, the followers' opinion in the network are more concentrated.

Key words: opinion leaders, opinion similarity, closeness, opinion guidance

1. Introduction

With the rapid development of the Internet technology, an online society, with complicating, diverse form, and huge, is gradually formed (Watts & Dodds, 2007). Especially the new online content development, such as live broadcast and short videos, promoted the content sharing, user consumption scenarios, and further promoted the development of the digital economy. There are some celebrities in online community, who usually have superior social status or social prestige, and have more experience and information of products or services than ordinary users, and

* Corresponding author. Tel.: +86-15982059756
E-mail address: chenjia@swufe.edu.cn

10.1016/j.procs.2023.07.007

affect the attitude and behavior of others through communication (Lyons & Henderson, 2005). These people who have sufficient professional knowledge in specific fields and can affect others are called opinion leaders (Lazarsfeld,1944). It is worth noted that users are affected by the many opinion leaders in social networks holding different opinions. In addition, as an open and real-time interactive environment, users will be affected by friend' opinions. For example, similar opinions between closed connected users often produce similar attitudes, that is, the similarity of opinions and closeness of users play an important role in users dynamic decision-making (Li, et al., 2013; Neubaum & Kraemer, 2015).

Based on the theory of opinion dynamics, this paper establishes an integrated opinion similarity and closeness of opinion leaders to describe the interactive of opinion leaders and followers. This model significance to explore the factors that affect the dynamic decision-making process of users in social networks. The results of this paper can help enterprises to guide users with opinion leaders, thereby enhancing the effect of information dissemination.

2. Literature review

2.1 The impact of pinion leaders

The number of adjacent nodes is important characteristics of opinion leaders in social network. Calculate the centrality and tightness based on the interaction time of nodes in the network, and can effectively identify opinion leaders in social networks. Based on the characteristics of opinion leaders in social networks, studies have found that opinion leaders have a significant impact on the dissemination of information (Jain, et al., 2020; Yang, et al., 2018). By constructing the impact of opinion leaders on the spread of public events, study found that the opinion leaders have strong capabilities of communication and information dissemination in the Weibo platform, which can effectively affect the opinions of supporters, neutralists and opponents (Jin & Wang, 2013). In addition, some scholars use opinion dynamics model to explore the influence mechanism of opinion leaders in social networks. Based on environmental uncertainty, establishing leaders-followers' opinion dynamic models, the study explores the evolution of followers' opinion with single and multiple opinion leaders (Zhao, et al., 2016). With natural reversal parameters, Xiao et al. (2020) discusses the dynamic feature of the natural reversal o of opinion leaders and ordinary groups' opinion. Then, considering two competitive advertising opinions leaders, Chen et al. (2021) establishing a bounded confident model based on opinion dynamics to discuss the effects of opinion leaders on opinion followers.

At the same time, studies show that the evolution of users' opinion is affected by distance of opinions and relationship during the impact of opinion leaders on the user's opinions. High similarity of individual opinions helps the establishment of trust and the achievement of opinion consensus, and the distance between the individuals' relationship, that is, intimacy, will trigger the resonance the convergence of attitudes and behaviors of users.

2.2 The effect of similarity opinions

In virtual environment of social network, the differences of individuals are ignored, therefore, individuals pay more attention to the similarity of perception (Chung, 2019). In social networks, individuals will provide comments and reference, sharing suggestions based on trust relationships, which affects interaction between users (Dong et al., 2018; Moradi & Ahmadian, 2015). Therefore, users who have similar opinions in social networks will pay attention to the same account, comments and communication below the same content, and even become friends. Open interaction in social networks leads to a higher transparency between users' opinions, and the similarity opinions of the target friends or strangers will lead to individuals strengthen the firmness of others' opinions and aggregation of the group.

Studies have shown that similar opinions between individuals will indeed cause more attraction and interaction of individuals, and there is a positive relationship between the opinion difference and evolution of opinions (Goel et al., 2010). Comprehensive opinion similarity and credibility can better analyze the group decision-making model and study the non-coordinated behavior of management decisions (Takács et al., 2016).

2.3 The effect of closeness

Communication and interaction in social networks help weaken the decline in social relations over time, and the closeness plays an important role in it (Roberts & Dunbar, 2011). Closeness, also called intimacy, refers to the

tightness or connection between individuals in social networks. Social relationships are the important channels for information dissemination. The intimacy and interaction frequency of individuals will have a significant impact on the communication of information (Tsai & Ghoshal, 1998). In fact, individuals tend to interact with individuals who are similar to their own social relationships. This kind of interpersonal similarity increases social interaction, group knowledge sharing and communication, making the connection between individuals closer (Makela et al., 2007). Therefore, the intimacy between individuals can be regarded as interpersonal similarity between the two individuals. Some scholars use the proportion of common friends between the two individuals to represent interpersonal similarity (Zhang et al., 2021; Roberts & Dunbar, 2011). Study has found that the less friends between the two individuals, the lower the intimacy of the two individuals (Neubaum & Kraemer, 2015).

3. Integrated HK model based on opinion similarity and closeness

3.1 HK model

Assume the set of nodes in the social network are $N=\{1,2,...,n\}$, N is the number of individuals in the network. $X(t)=\{x(1),x(2),...,x(n)\}$ is the set of opinions of individual i at time t. If $I(i,x(t))=\left\{1\le j\le n\middle|\left|x_i(t)-x_j(t)\right|\le\varepsilon, i\ne j\right\}$, the opinion update rule of individual i at time $t+1$ is as follows (Hegselmann & Krause, 2002):

$$x_i(t+1)=\frac{\sum_{j\in I(i,x(t))}a_{ij}x_j(t)}{\sum_{j\in I(i,x(t))}a_{ij}} \tag{1}$$

where ε is the bounded trust level of the individual, and a_{ij} is the weight that individual i assigns to the individual j at time t.

3.2 Integrated HK model based on opinion similarity and closeness

Whether in real society or online social networks, individuals tend to communicate with others who have similar opinions. The more similar opinions between individuals, the more likely to be affected by the individual. At the same time, the lower the similarity of the individual opinion, the lower the probability of the individual's interaction, and the smaller it is affected by the individual (Du et al., 2020). Therefore, the definition of similar opinions in this paper is as followed:

$$SD_{ij}=\begin{cases}1-\dfrac{1}{\varepsilon}\left|x_i-x_j\right|, j\in I(i,x(t))\\ 0, otherwise\end{cases} \tag{2}$$

where $SD_{ij}\in[0,1]$, ε is the bounded trust level of the individual, $\varepsilon\in[0,1]$. $\left|x_i-x_j\right|$ represents the absolute value of the opinion of node i and j.

In addition, considering the number of common friends may have different impact on both interactive individuals. If the proportion of the number of common friends in in the number of individual friends accounted for a little number, this shows that the intimacy of interactive individuals is low. Conversely, if the number of common friends in the number of individual friends accounted for a large number, it means that the intimacy of both parties is higher. Therefore, we define the intimacy is as followed:

$$R_{ij}=\begin{cases}\dfrac{1}{|P(j)|}, a_{ij}=1\\ \left(\dfrac{|\Gamma(i)\cap\Gamma(j)|}{|P(j)|}\right)^2, |\Gamma(i)\cap\Gamma(j)|\ne 0, a_{ij}=0\\ 0, otherwise\end{cases} \tag{3}$$

where $\Gamma(i)$ represents the neighbour node collection of nodes i , $\Gamma(j)$ represents the neighbour node collection of nodes j . $|\Gamma(i)\cap\Gamma(j)|$ is the number of common friends between node i and node j . If the nodes have a common neighbour in the boundary confidence, the shortest paths between the two nodes in the network is 1 or 2. When $a_{ij}=1$, the shortest path between the two individuals is 1, otherwise, when $a_{ij}=0$, the shortest path between the two individuals is 2. $P(j)$ represents the number of nodes directly connected to the node j ,that is, the first-order neighbour domain of node j . $|P(j)|$ indicates the number of nodes in the first-order neighbourhood of node j .

According to the bounded confidence theory, if $|x_i(t)-x_j(t)|\le\varepsilon$, the rule of opinion updated is as followed:

$$x_i(t+1)=\frac{\sum_{j\in I(i,x(t))} SD_{ij}\cdot R_{ij}x_j(t)}{\sum_{j\in I(i,x(t))} SD_{ij}\cdot R_{ij}} \tag{4}$$

where SD_{ij} represents the similarity between the opinion of node i and node j , $SD_{ij}\in[0,1]$. R_{ij} is the closeness of node i and node j , $R_{ij}\in[0,1]$. $I(i,x(t))=\left\{1\le j\le n\middle|\left|x_i(t)-x_j(t)\right|\le\varepsilon, i\ne j\right\}$, $\varepsilon\in[0,1]$.

Suppose there are n individuals in the social network, which contains two opinion leader groups. The number of positive opinion leaders is q_1 , and the number of negative opinion leader is q_2 , $q=q_1+q_2$. Therefore, the number of followers is $n-q$.

Assuming $[e_{ij}]_{N\times N}$ is the adjacency matrix of the social network, if e_{ij} = 1, which means a connection exists between individuals i and j in the network; otherwise, $e_{ij}=0$ denotes no connection between individuals i and j .

According to HK model, when $|x_i(t)-x_j(t)|\le\varepsilon$, the rule of positive opinion leader groups' opinion updated is defined as:

$$x_i^P(t+1)=(1-\lambda)\frac{\sum_{j\in L_1(i,x(t))} b_{ij}^t e_{ij}x_j(t)}{\sum_{j\in L_1(i,x(t))} b_{ij}^t}+\lambda d \tag{5}$$

where $i=1,2,...q_1$, $L_1(i,x(t))=\left\{1\le j\le q_1\middle|\left|x_i(t)-x_j(t)\right|\le\varepsilon_i^{\,L}, i\ne j\right\}$ is the set of positive opinion leaders. $b_{ij}^t(t)=\begin{cases}0, \textit{otherwise}\\ 1, \left\|x_j(t)-x_i(t)\right\|\le\varepsilon_i^{\,L}\end{cases}$, $\varepsilon_i^{\,L}$ is the bounded confidence level of the opinion leader group. λ indicates the degree of influence of node i by the target opinion, d is the value of target opinion.

As mentioned before, when $|x_i(t)-x_j(t)|\le\varepsilon$, the rule of negative opinion leader groups' opinion updated is defined as:

$$x_i^N(t+1)=(1-\mu)\frac{\sum_{j\in L_2(i,x(t))} b_{ij}^t e_{ij}x_j(t)}{\sum_{j\in L_2(i,x(t))} b_{ij}^t}+\mu g \tag{6}$$

where $i=1,2,...q_2$, $L_2(i,x(t))=\left\{1\le j\le q_2\middle|\left|x_i(t)-x_j(t)\right|\le\varepsilon_i^{\,L}, i\ne j\right\}$ is the set of

negative opinion leaders. $b_{ij}^{t}(t)=\begin{cases}0, \ otherwise\\ 1, \ \left\|x_j(t)-x_i(t)\right\|\le \varepsilon_i^{\ L}\end{cases}$, $\varepsilon_i^{\ L}$ is also the bounded confidence level of the opinion leaders. μ indicates the degree of influence of node i by the target opinion, g is the value of target opinion.

The opinion update model for opinion followers is defined as:

$$x_i^F(t+1)=(1-\alpha_i-\beta_i)\frac{\sum_{j\in F(i,x(t))} SD_{ij}\cdot R_{ij}x_j(t)}{\sum_{j\in F(i,x(t))} SD_{ij}\cdot R_{ij}}+\alpha_i\frac{\sum_{j\in L_3(i,x(t))} c_{ij}^{t}e_{ij}x_j(t)}{\sum_{j\in L_3(i,x(t))} c_{ij}^{t}}+\beta_i\frac{\sum_{j\in L_4(i,x(t))} c_{ij}^{t}e_{ij}x_j(t)}{\sum_{j\in L_4(i,x(t))} c_{ij}^{t}} \quad (7)$$

where $i=1,2,...n-q$, $F(i,x(t))=\left\{1\le j\le n-q \left\|x_i(t)-x_j(t)\right\|\le \varepsilon_i^{\ F}, i\ne j\right\}$ is the set of opinion followers. $c_{ij}^{t}(t)=\begin{cases}0, \ otherwise\\ 1, \ \left\|x_j(t)-x_i(t)\right\|\le \varepsilon_i^{\ F}\end{cases}$, $\varepsilon_i^{\ F}$ is the bounded confidence level of the opinion followers. Within the bounded confidence level of the followers, $L_3(i,x(t))=\left\{1\le j\le q_1 \left\|x_i(t)-x_j(t)\right\|\le \varepsilon_i^{\ F}, i\ne j\right\}$ and $L_4(i,x(t))=\left\{1\le j\le q_2 \left\|x_i(t)-x_j(t)\right\|\le \varepsilon_i^{\ F}, i\ne j\right\}$ indicate the set of positive opinion leaders and negative opinion leaders of the node i connection, respectively. α_i and β_i are the trust degree of followers to positive opinion leaders and negative opinion leaders. As before, SD_{ij} represents the similarity between the opinion of node i and node j. R_{ij} is the closeness of node i and node j.

4. Simulation experiments

4.1 The parameter of simulation experiment

When the node size in the network reaches 2000, the evolution of the group opinions tends to be stable, which means that the further expansion of the network size will not have a significant impact on nodes of entire group (Zhao et al., 2018), so the experiments of this paper set 2000 nodes in the network. From Fig.1 and Fig.2, we can see the distribution of node degree and the number of common friends' distribution of 2000 nodes.

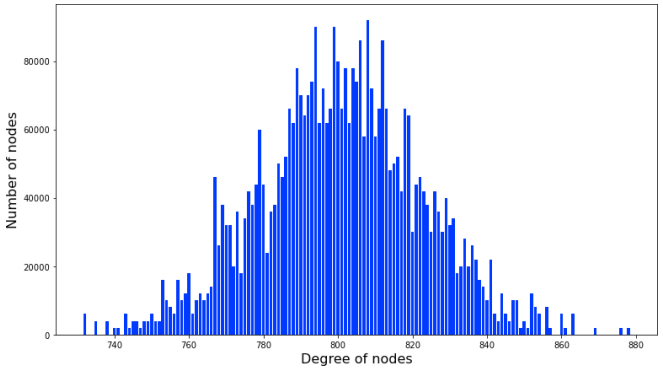

Figure 1. $|P(j)|$ distribution

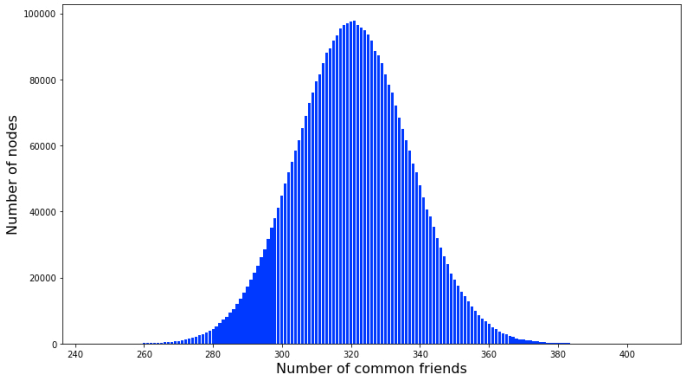

Figure 2. The number of common friends' distribution

Based on the $|P(j)|$ and common friends' distribution, we investigate the influence of similarity opinion and closeness on the followers' opinion dynamics process. The assumptions in the simulation experiments are as Table 1.

Table1. Experimental parameter

Nodes of network	N=2000
The proportion of positive and negative opinion leaders	$P_P = P_N = 0.05$
Network non-connection rate	0.6
The initial opinion of the individual obeys the uniform distribution	$x_i(0) \in [-0.5, 0.5]$
The target opinion of positive and negative opinion leaders	$d = 0.5$; $g = -0.5$
The weight of target opinion	$\lambda = \mu = 0.5$
The trust degree of followers to opinion leaders	$\alpha_i = \beta_i = 0.4$
The bounded confidence level of opinion leaders	$\varepsilon_i^L = 0.25$
The bounded confidence level of followers	$\varepsilon_i^F \in [0.3, 0.8]$

4.2 Experiment results and discussion

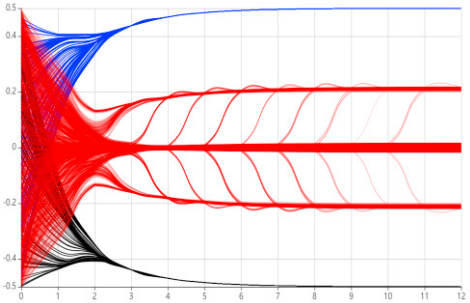

Figure 3. The opinion evolution with high similarity opinion

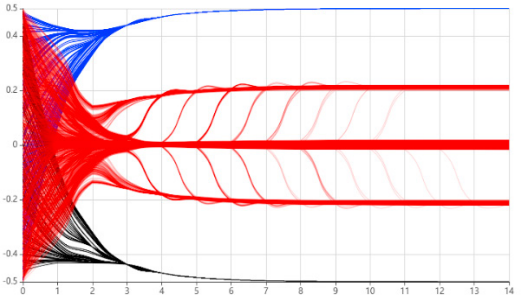

Figure 4. The opinion evolution with low similarity opinion

From Fig.3 and Fig.4, blue, black and red solid lines represent positive opinion leaders, negative opinion leaders and opinion followers, respectively. We can see from Fig.3 and Fig.4, regardless of high or low similarity opinion, opinion leaders can quickly converge (within 5-time steps) to the subgroup of target opinion. However, the opinion evolution of followers is more complicated. With a high similarity of opinion, the opinion of followers finally converges three opinion clusters, which are concentrated on the opinion value of -0.2, 0 and 0.2, respectively. With a low similarity of opinion, the opinion of followers finally converges three opinion clusters too. Some of opinions are concentrated on near the opinion value of 0, others' opinions are concentrated on the opinion value of -0.2 and 0.2. It is found that, with a high similarity opinion, after the end of evolution, and the concentration proportion of the follower' opinion in the network is 0.686. Additionally, with a low similarity opinion, the concentration proportion of the follower' opinion in the network is 0.655. This shows that, with a high similarity opinion, follower opinions are more converged and suitable for guidance. Therefore, when guiding users' opinion, opinion leaders can express their own opinion with high similarity to the perspective of users, so that users can follow their opinions faster.

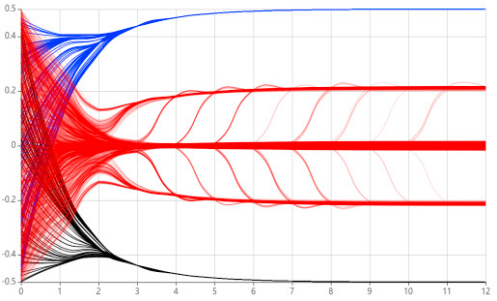

Figure 5. The opinion evolution with high closeness

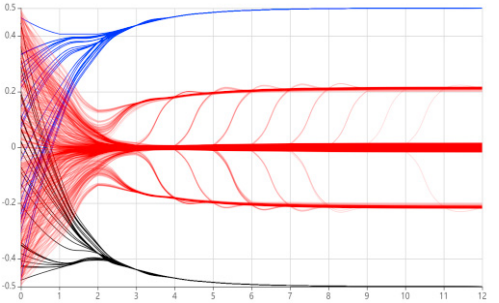

Figure 6. The opinion evolution with low closeness

From Fig. 5 and Fig. 6, similarly, the opinion of opinion leaders is quickly converged into target opinion in 5-time steps. The final of followers' opinions are converged in three clusters, which are concentrated in the opinion of -0.2, 0 and 0.2. and the maximum opinion clusters are concentrated in middle opinion value. It is found that, with a high closeness, the number of followers' opinion at interval [-0.1, 0.1] is 827, however, with a low closeness, the number of followers' opinion at interval [-0.1, 0.1] is 395. Therefore, with a high closeness, the opinion of followers in the network are more concentrate. That is, with more common friends between opinion leaders and followers, it is easier to guide the opinion of the followers and have a better effect.

5. Conclusion

In the social network, opinion leaders have an important impact on the formation of other users' opinion. This paper constructed an integrated HK model from opinion similarity and closeness to discusses the guidance of the leader on other users. The results have shown that the higher opinion similarity between the opinion leaders and followers, there will be less opinion clusters of opinion followers. And if there are more common friends between the opinion leaders and followers, the opinion of followers will be more concentrated. These results can provide guidance and support for information dissemination in social media platforms.

Acknowledgements

This work was supported in part by grants from the National Social Science Foundation of China(#22BGL236).

References

[1] Watts, D. J., & Dodds, P. S. (2007). Influentials, networks, and public opinion formation. *Journal of consumer research*, 34(4), 441-458.

[2] Lazarsfeld, P. F., Berelson, B., & Gaudet, H. (1944). The people's choice, ser. The people's choice.

[3] Lyons, B., & Henderson, K. (2005). Opinion leadership in a computer‐mediated environment. *Journal of Consumer Behaviour: An International Research Review*, 4(5), 319-329.

[4] Li, Y., Ma, S., Zhang, Y., & Huang, R. (2013). An improved mix framework for opinion leader identification in online learning communities. *Knowledge-Based Systems*, 43, 43-51.

[5] Neubaum, G., & Kraemer, N. C. (2015). My friends right next to me: a laboratory investigation on predictors and consequences of experiencing social closeness on social networking sites. *Cyberpsychology Behavior & Social Networking*, 18(8), 443.

[6] Jain, L., Katarya, R., & Sachdeva, S. (2020). Opinion leader detection using whale optimization algorithm in online social network. *Expert Systems with Applications*, 142, 113016.

[7] Yang, L., Qiao, Y., Liu, Z., Ma, J., & Li, X. (2018). Identifying opinion leader nodes in online social networks with a new closeness evaluation algorithm. *Soft Computing*, 22(2), 453-464.

[8] Jin, X., & Wang, Y. (2013). Research on social network structure and public opinions dissemination of micro-blog based on complex network analysis. *Journal of Networks*, 8(7), 1543.

[9] Xiao, R., Yu, T., & Hou, J. (2020). Modeling and simulation of opinion natural reversal dynamics with opinion leader based on HK bounded confidence model. *Complexity*, 2020, 1-20.

[10] Zhao, Y., Zhang, L., Tang, M., & Kou, G. (2016). Bounded confidence opinion dynamics with opinion leaders and environmental noises. *Computers & Operations Research*, 74, 205-213.

[11] Chen, J., Kou, G., Wang, H., & Zhao, Y. (2021). Influence identification of opinion leaders in social networks: an agent-based simulation on competing advertisements. *Information Fusion*, 76, 227-242.

[12] Chung, J. E. (2019). Peer influence of online comments in newspapers: applying social norms and the social identification model of deindividuation effects (SIDE). *Social Science Computer Review*, 37(4), 551-567.

[13] Moradi, P., & Ahmadian, S. (2015). A reliability-based recommendation method to improve trust-aware recommender systems. *Expert Systems with Applications*, 42(21), 7386-7398.

[14] Dong, Y., Zha, Q., Zhang, H., Kou, G., Fujita, H., Chiclana, F., & Herrera-Viedma, E. (2018). Consensus reaching in social network group decision making: Research paradigms and challenges. *Knowledge-Based Systems*, 162, 3-13.

[15] Goel, S., Mason, W., & Watts, D. J. (2010). Real and perceived attitude agreement in social networks. *Journal of personality and social psychology*, 99(4), 611.

[16] Takács, K., Flache, A., & Mäs, M. (2016). Discrepancy and disliking do not induce negative opinion shifts. *PloS one*, 11(6), e0157948.

[17] Roberts, S. G., & Dunbar, R. I. (2011). Communication in social networks: Effects of kinship, network size, and emotional closeness. *Personal Relationships*, 18(3), 439-452.

[18] Tsai, W., & Ghoshal, S. (1998). Social capital and value creation: The role of intrafirm networks. *Academy of management Journal*, 41(4), 464-476.

[19] Makela, K., Kalla, H. K., & Piekkari, R. (2007). Interpersonal similarity as a driver of knowledge sharing within multinational corporations. *International Business Review*, 16(1), 1-22.

[20] Zhang, H., Liang, X., & Qi, C. (2021). Investigating the impact of interpersonal closeness and social status on electronic word-of-mouth effectiveness. *Journal of Business Research*, 130, 453-461.

[21] Hegselmann, R., & Krause, U. (2002). Opinion dynamics and bounded confidence models, analysis, and simulation. *Journal of artificial societies and social simulation*, 5(3), 1-33.

[22] Du, Z. J., Yu, S. M., & Xu, X. H. (2020). Managing noncooperative behaviors in large-scale group decision-making: Integration of independent and supervised consensus-reaching models. *Information Sciences*, 531, 119-138.

[23] Zhao, Y., Kou, G., Peng, Y., & Chen, Y. (2018). Understanding influence power of opinion leaders in e-commerce networks: An opinion dynamics theory perspective. *Information Sciences*, 426, 131-147.