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PAPER

Strategy and Practice for Improving Supply Chain Management through Mobile Interaction Technology

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ABSTRACT

With the rapid development of the global economy and the continuous advancement of information technology, supply chain management is facing increasingly complex challenges. Traditional supply chain management methods often struggle to meet rapidly changing market demands and efficient material allocation needs, and there is an urgent need for new technological means to enhance their flexibility and response speed. Mobile interactive technology, with its ability to transmit information across time and space, has gradually become an important innovative tool in the field of supply chain management. By introducing mobile interaction technology, various links in the supply chain can achieve more immediate and efficient communication and collaboration, thereby promoting the optimization and improvement of the entire supply chain. Although many studies have explored the application of mobile technology in the supply chain, most of them focus on the analysis of single links or specific cases, lacking a systematic and comprehensive perspective. In response to this research gap, after systematically analyzing the multidimensional impact of mobile interaction technology on supply chain management, corresponding strategy and practical framework were proposed in this study. The research content of this study mainly includes four aspects: a) the analysis of the impact of supply chain materials; b) the analysis of the impact of mobile interaction on improving supply chain management; c) the analysis of the sustained impact scope of mobile interaction in supply chain collaboration activities; d) the adjustment strategy for the priority of supply chain collaboration activities. This study not only provides a new perspective for supply chain management theory but also provides specific guidance and decision support for the application of technology in enterprise practice, which has high academic value and practical significance.

KEYWORDS

supply chain management, mobile interaction technology, collaboration activities, impact analysis, priority adjustment

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1 INTRODUCTION

With the rapid development of the globalized economy and the continuous advancement of information technology, supply chain management is facing increasingly complex challenges [1–5]. Especially in the context of market demand fluctuations, tight production cycles, and cross-regional coordination, problems, such as inefficiency and lag, have gradually been exposed in the traditional supply chain management models [6, 7]. In recent years, the popularity of mobile communication technology and intelligent terminals has provided new solutions for supply chain management. By integrating mobile interactive technology into various links of the supply chain, instant information transmission, efficient allocation of materials, and rapid response to decisions can be achieved, significantly improving the flexibility and response speed of the supply chain and promoting the development of supply chain management models towards higher efficiency and intelligence [8–11].

Although many scholars have explored the application of mobile technology in the supply chain, existing research mostly focuses on specific technology application cases, lacking systematic analysis. In particular, the comprehensive research on how mobile interaction technology affects supply chain management from multiple dimensions is still relatively weak [12–17]. Most existing research methods remain at the theoretical framework level, lacking in-depth analysis of practical operations. In addition, they have not sufficiently explored the collaborative mechanism and dynamic adjustment strategy in the supply chain [18–20]. Furthermore, some studies have taken a lopsided view in evaluating the implementation effect, failing to fully consider the long-term impact of mobile technology.

The main research content of this study includes four aspects: firstly, the analysis of the influencing factors of supply chain materials and their impact on supply chain efficiency; secondly, the exploration of the impact and application of mobile interactive technology aimed at improving supply chain management; thirdly, the investigation of the sustained impact scope of mobile interaction technology in supply chain collaboration activities; finally, the proposal of adjusting the priority of supply chain collaboration activities reasonably based on the application of mobile interaction technology. Through in-depth analysis of these issues, this study is expected to provide not only new perspectives for innovation in supply chain management theory but also strategic support and a decision-making basis for enterprises to effectively apply mobile interaction technology in practical operations, thereby enhancing the overall efficiency and competitiveness of the supply chain.

2 ANALYSIS OF THE IMPACT OF SUPPLY CHAIN MATERIALS

The impact of supply chain materials on supply chain collaboration activities is mainly reflected in two dimensions: the quantity and type of materials. The quantity of supply chain materials is closely related to the demand for materials in supply chain collaboration activities. When the demand for collaboration activities in the supply chain is high, the adequacy of material supply directly determines the progress and execution effectiveness of collaborative projects. If the supply chain material supply is insufficient, especially when the demand exceeds the supply capacity, the collaboration activities of the supply chain often face the risk of delay or even interruption. Therefore, ensuring a stable supply of materials is crucial for ensuring the timely completion of collaboration activities. Meanwhile, there are significant differences in risk and competition intensity among different types of supply chain materials. Materials with substitutability usually have lower risks because once there is a problem with the supply of a certain material, it can be quickly replenished through alternative materials to maintain the continuity of the collaborative project. However, materials that are not replaceable carry a higher risk. Once there is a supply interruption, it may lead to the stagnation of collaboration activities or even the failure of the entire project. Therefore, for different types of materials, especially irreplaceable materials, it is necessary to strengthen control and ensure their supply stability.

As for the measurement of the substitutability of supply chain materials, an analysis was conducted in this study mainly from three aspects, namely, material substitutability, substitution rate, and acquisition cost. The substitutability of supply chain materials depends on whether different materials can provide the same or similar work capabilities. If the supply chain materials have multiple substitutable materials, which leads to greater substitutability and lower difficulty in acquisition, the supply chain management is more flexible. For example, when there is a supply problem with a certain material, materials with more alternative options can be quickly replaced by substitutes, reducing the risk of supply interruption. The substitution rate of supply chain materials refers to the difference in work efficiency between different materials while completing the same amount of work. If a substitute material for a certain material requires more input to complete the same task, then its substitution rate is lower; otherwise, the substitution rate is higher. Materials with low substitution rates may lead to additional material consumption, thereby affecting the overall efficiency of supply chain activities. The acquisition cost ratio takes into account the cost difference between alternative supply chain materials and the original materials during the acquisition process. Generally speaking, materials with lower substitution rates often require higher prices to meet the same demand, which increases the cost of obtaining substitute materials and further reduces their substitutability.

Based on the above analysis, to meet the conditions of existing supply chain materials, the comprehensive impact of supply chain materials on supply chain collaboration activities was mainly measured in this study from the following three aspects, namely, the demand intensity of supply chain collaboration activities on various supply chain materials, the risk of supply chain materials, and the degree of limitation on the overall allocation of supply chain materials. Assuming that the execution of a supply chain collaboration project requires multiple supply chain materials, where the set of supply chain material types required for supply chain collaboration activity u is α, then the comprehensive impact of supply chain materials on supply chain collaboration activity u can be calculated.

a) The demand intensity of supply chain collaboration activities on various supply chain materials: The demand intensity of supply chain materials refers to the degree to which a certain material is relied upon by multiple activities during collaboration activities. When the demand intensity for a certain supply chain material is high, it is crucial for the execution of collaboration activities. Especially in situations of tight supply of materials, materials with high demand intensity will become bottlenecks, leading to delays or interruptions in the collaboration activities of the entire supply chain. Specifically, a certain supply chain material required for supply chain collaborative activity u is represented by G, its supply quantity is represented by E^G, and the demand for it by supply chain collaborative activity is represented by e_u^G. Therefore, the demand intensity π_u^G of the supply chain collaborative activity for supply chain material G is:

$$\pi_u^G = \frac{e_u^G}{E^G} \tag{1}$$

b) The degree of limitation on the overall allocation of supply chain materials: The degree of limitation on the overall allocation of supply chain materials is another key factor affecting the supply chain collaboration activities. It refers to the adjustability and flexibility of material allocation in multiple supply chain collaboration activities. When supply chain materials are shared among multiple projects or activities, the overall allocation of materials may be limited by the demands of other activities. If there is significant competition or conflict in the allocation process of certain key materials, it may result in some collaboration activities not proceeding smoothly as planned and even affect the operational efficiency of the entire supply chain. The degree of limitation of each supply chain material in the overall allocation of supply chain collaboration projects was calculated. Assuming that the degree of limitation of supply chain material G in the overall allocation of supply chain collaboration projects is represented by q^G, the average demand for material G in supply chain collaboration activities is represented by e^{-G}, and the maximum supply of G is represented by E^G.

$$q^G = e^{-G}/E^G \tag{2}$$

c) The risk of supply chain materials: The risk of supply chain materials is also an important dimension for measuring their impact on supply chain collaboration activities. It is mainly reflected in their substitutability and difficulty of acquisition. When materials have high risk, it means that they are irreplaceable or their substitution cost in supply chain collaboration activities is high. Once the supply of such materials is interrupted, it often leads to the suspension of collaboration activities or the failure of projects. The unit substitution rate of the j-th substitute material for the scarce material G is represented by λ_C^j, the quantity of material G required per unit time for supply chain collaboration activity u is represented by v_u, and the supply quantity of the j-th substitute material C per unit time is represented by E_{TC}^j. Let G be a shortage of supply chain material, which has V alternative supply chain materials C. When calculating the tension of the j-th alternative material for supply chain material G in the supply chain collaborative activity u, then the coefficient β_C^j was defined as follows:

$$\beta_C^j = \frac{\lambda_C^j \times v_u}{E_{TC}^j} \tag{3}$$

The smaller the β_C^j value, the greater the substitutability of G and the lower its risk.

Furthermore, the acquisition cost ratio of the j-th substitute material for G was calculated. Assuming that the cost of obtaining the j-th substitute material C for unit material G is represented by Z_C^j, and the cost of obtaining unit material G is represented by Z_G. The coefficient b was defined as follows:

$$b_C^j = \frac{Z_C^j}{Z_G} \tag{4}$$

The larger the value of b, the more difficult it is to obtain the alternative supply chain material and the less substitutable it is. The minimum substitutability of supply chain material G in supply chain collaborative activity u was calculated. Assuming that the number of potential substitute material types available to G is represented by V, the coefficient n_u^G was defined as follows:

$$n_u^G = \frac{V}{MAX_j\left(\beta_C^j \times b_C^j\right)} \tag{5}$$

At the same time, the following condition applies:

$$n_u^G = MAX\left(1, \frac{V}{MAX_j\left(\beta_C^j \times b_C^j\right)}\right) \tag{6}$$

The larger the value of n_u^G, the greater the possibility of obtaining sufficient materials to replace G, and the lower the material risk. Based on the above analysis, combined with the demand intensity of supply chain collaboration activities on supply chain materials, the degree of limitation on the allocation of supply chain materials in supply chain collaboration activities, and the risk of supply chain materials, the comprehensive impact coefficient of supply chain materials was calculated. Assuming that the comprehensive impact coefficient of supply chain materials on supply chain collaboration activity u is represented by EE_u, and the set of supply chain materials required for supply chain collaboration activity u is represented by φ_u, the coefficient EE_u was defined as follows:

$$EE_u = \sum_{G \in \theta_u} \pi_u^G \times \frac{q^G}{n_u^G} \tag{7}$$

The larger the coefficient EE_u value, the greater the impact of supply chain materials on supply chain collaboration activity u. Priority should be given to executing supply chain collaboration activities with greater material constraints, avoiding these activities being affected by insufficient supply chain materials in the later stages of the supply chain collaboration project, thereby affecting the project cycle.

3 ANALYSIS OF THE IMPACT OF MOBILE INTERACTION ON IMPROVING SUPPLY CHAIN MANAGEMENT

The incompleteness, lag, and change of mobile information are key factors contributing to the uncertainty of the cycle of supply chain collaboration projects. Figure 1 shows the supply chain mobile information exchange management mode. In the initial stage of supply chain collaboration projects, only some of the required mobile information can be obtained, and other information can only be gradually fed back through mobile interactions between activities during project implementation. With the advancement of collaboration activities, the lag and changes in information feedback may cause delays in supply chain collaboration projects, thereby affecting the overall progress and cost of the projects. Especially in the case of poor information flow and delayed interaction feedback, it may lead to errors in supply chain decision-making or untimely adjustments, thereby increasing additional costs and time consumption. Therefore, the impact of supply chain collaboration activities on supply chain collaboration projects was measured in this study from the perspective of mobile interaction, aiming to reveal the bottlenecks and problems of information flow in supply chain collaboration activities and provide targeted optimization suggestions for improving supply chain management.

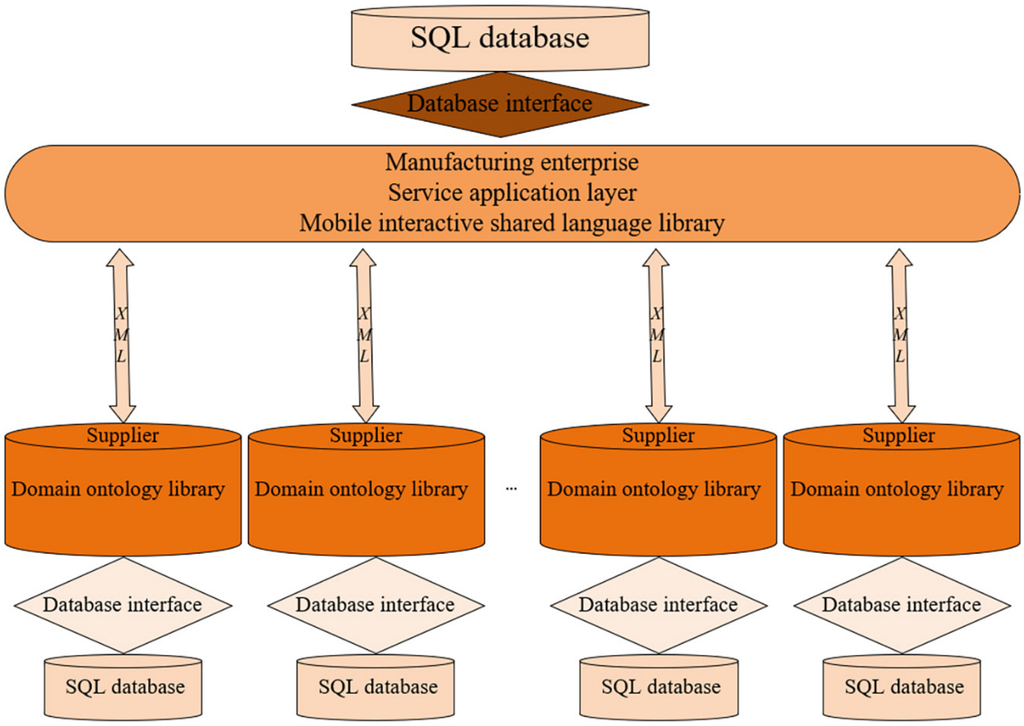


Fig. 1. Supply chain mobile information interaction management mode

In complex supply chain collaboration projects, feedback from mobile interactions is inevitable, and the feedback mainly comes from planned and unplanned feedback. Planned feedback is usually generated due to the coupling within the collaboration activities of the supply chain, such as incomplete information transmitted when upstream activities are not completed or the need for downstream activities to receive and integrate complete information during execution. This type of feedback helps to adjust project progress and reduce risks. Relatively speaking, unplanned feedback is often caused by unreasonable arrangements or communication barriers in the execution of supply chain collaboration activities, especially when the execution sequence of supply chain collaboration activities is not properly arranged, or when there are execution errors, incompatibility, or poor information flow between upstream and downstream activities, and it may lead to significant delays or cost overruns. Usually, changing the execution sequence of collaboration activities can lead to significant changes in the time and cost of supply chain projects, indicating that feedback is not only the result of information transmission but may also generate more complex chain reactions during the execution process. Therefore, analyzing the feedback from the perspective of mobile interaction can reveal information flow bottlenecks and risk points in supply chain collaboration projects and provide decision support for optimizing supply chain management processes and improving information flow efficiency.

In complex supply chain collaboration projects, the interdependence and information transmission between activities are crucial. The process and delay impact of mobile information flow interaction in supply chain collaboration activities was analyzed in this study based on the Design Structure Matrix (DSM). Through the DSM, it is possible to clearly identify the relationships and feedback paths between supply chain collaboration activities, thereby revealing which activity execution order leads to information flow lag and feedback delay.

Calculating the delay time caused by feedback on supply chain collaboration activities is the first step in evaluating the impact of mobile information flow interactions on supply chain projects. The flow of mobile information between supply chain collaboration activities is interdependent. When there is a delay in the execution or feedback of a certain activity, it may cause the upstream activities of that activity to be unable to complete on time, thereby affecting the initiation or progress of downstream activities. Specifically, when calculating the delay time of the supply chain collaboration project caused by the feedback of activity k to upstream activity u, the coefficient ε_{uk} was defined as follows:

$$\varepsilon_{uk} = ED(u,k) \times RU(u,k) \times \sum_{i=u}^{v} (s_i \times ED(i,u) \times EU(i,u)), u \in (u,k-1) \tag{8}$$

Assuming that the workload of supply chain collaborative activity i is represented by s_i. When $i = u$, the values of $ED(u, u)$ and $EU(u, u)$ are 1. As for the delay time of supply chain collaboration projects caused by all feedback from supply chain collaboration activity k, the coefficient ε_u was defined as follows:

$$\varepsilon_k = \sum_{u=1}^{k-1} \varepsilon_{uk} \tag{9}$$

The delay cost caused by feedback on supply chain collaboration activities was further calculated. Delay not only affects the completion time of the project but also leads to additional cost expenditures, including but not limited to labor costs, equipment usage fees, material procurement costs, and management expenses. The delay caused by mobile information feedback can disrupt the original sequence of supply chain collaboration activities, resulting in ineffective utilization of resources as planned and idler and waiting time, thereby increasing the total cost of the project. Specifically, when calculating the delay cost of supply chain collaboration projects caused by feedback from activity k to upstream activity u, the coefficient z_{uk} was defined as follows:

$$z_{uk} = ED(u,k) \times EU(u,k) \times \sum_{i=u}^{v} (s_i \times ED(i,u) \times EU(i,u)), u \in (u,k-1) \tag{10}$$

Assuming that the planned cost of supply chain collaboration activity i is represented by Z_i, as for the delay cost of supply chain collaboration projects caused by all feedback from supply chain collaboration activity k, the coefficient z_k was defined as follows:

$$z_k = \sum_{u=1}^{k-1} z_{uk} \tag{11}$$

4 ANALYSIS OF THE SUSTAINED IMPACT SCOPE OF MOBILE INTERACTION IN SUPPLY CHAIN COLLABORATION ACTIVITIES

The duration of supply chain collaboration activities and the cumulative duration of subsequent activities within a limited supply chain collaboration project cycle are important indicators for measuring the scope of activity impact. The longer the duration of an activity, the greater its impact on the overall progress of the project. In particular, the delay information generated during the execution of the activity can affect the initiation or progress of subsequent activities. Therefore, in sorting adjustments, activities with longer durations should be prioritized for execution to reduce negative impacts on subsequent activities. In addition, the longer the cumulative duration of subsequent activities, the wider the impact of the activity on subsequent work and the entire supply chain collaboration project. The delay in mobile interaction feedback has a wider chain reaction in the project. This means that the execution and information flow of this activity can affect more subsequent activities, causing delays in project progress. Assuming that the immediate activity set of supply chain collaborative activity k is represented by T_k, and the duration of supply chain collaborative activity n is represented by s_n, the coefficient S_k was defined as follows:

$$S_k = \sum_{n \in T_k} s_n \tag{12}$$

5 DETERMINATION OF PRIORITY FOR ADJUSTING SUPPLY CHAIN COLLABORATION ACTIVITIES

Figure 2 shows the supply chain collaborative activity model in a mobile environment. Finally, the priority of supply chain collaboration activities was adjusted based on the grey relational analysis method in grey system theory. That is, by evaluating the correlation between multiple influencing factors, the priority execution order of each supply chain collaborative activity in the project was determined. Firstly, the grey relational analysis method was used to consider multiple indicators such as the comprehensive constraints of supply chain materials, delay time caused by feedback from supply chain collaboration activities, delay costs, and the impact scope of activities, and dimensionless processing was performed to enable unified comparison and analysis of data with different dimensions. Furthermore, by calculating the correlation coefficients and degrees between various supply chain collaboration activities and other activities, their impact on the overall progress and cost of the supply chain collaboration project was evaluated. In this process, the feedback delay generated by mobile interaction affects not only the execution progress of activities but also the execution efficiency of subsequent activities through information transmission, resulting in an increase in delay time and cost. Assuming that the relative difference between the comparison sequence A_u and the reference sequence A_0 on the j-th evaluation index is represented by $\zeta_u(j)$, the minimum absolute value difference between A_u and A_0 is represented by $\underset{u}{MIN}\,\underset{j}{MIN}\left|A_0(j) - A_u(j)\right|$, the maximum absolute value difference between them is represented by $\underset{u}{MAX}\,\underset{j}{MAX}\left|A_0(j) - A_u(j)\right|$, and the resolution coefficient is $\vartheta \in (0,1)$, then the grey correlation coefficient can be calculated as follows:

$$\zeta_u(j) = \frac{\underset{u}{MIN}\,\underset{j}{MIN}\left|A_0(j) - A_u(j)\right| + \vartheta\,\underset{u}{MAX}\,\underset{j}{MAX}\left|A_0(j) - A_u(j)\right|}{\left|A_0(j) - A_u(j)\right| + \vartheta\,\underset{u}{MAX}\,\underset{j}{MAX}\left|A_0(j) - A_u(j)\right|} \tag{13}$$

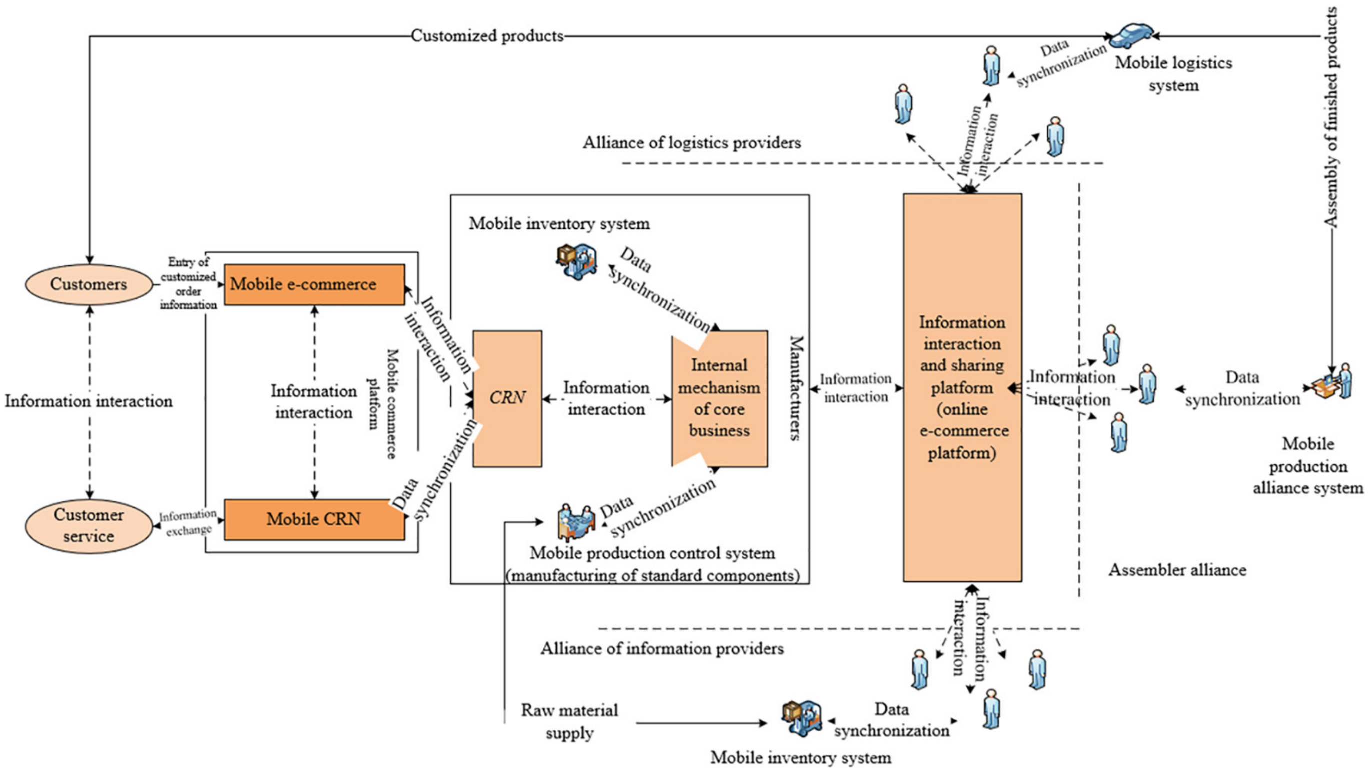


Fig. 2. Supply chain collaborative activity model in a mobile environment

Assuming that the weights of each indicator are represented by q_l, and $\sum_{l=1}^{v} q_l = 1$. The grey correlation degree h of the priority of supply chain collaboration activities can be calculated using the following formula:

$$h_u = \sum_{l=1}^{v} q_l \zeta_u(l) \tag{14}$$

6 EXPERIMENTAL RESULTS AND ANALYSIS

Table 1. Calculation process of priority adjustment for supply chain collaboration activities

Supply Chain Collaboration Activity ID	A	B	C	D	E	F	G	H
Comprehensive material impact coefficient	0.145	0.178	0.09	0.215	0.09	0.125	0.215	0.225
Normalization	0.512	0.714	0.123	0.985	0.125	0.378	0.826	1.125
Rework time/day	0.000	0.000	0.000	0.077	1.125	0.000	0.000	0.000
Normalization	0.000	0.000	0.000	0.032	0.415	0.000	0.000	0.000
Rework cost/10,000	0.000	0.000	0.000	0.077	0.936	0.000	0.000	0.000
Normalization	0.000	0.000	0.000	0.042	0.478	0.000	0.000	0.000
Duration of supply chain collaboration activities/day	3.125	7.265	5.124	28.265	2.895	5.124	14.265	5.265
Normalization	0.035	0.189	0.125	1.114	0.035	0.115	0.468	0.125
Duration of subsequent activities/day	215.235	48.235	43.256	121.253	98.235	98.526	98.256	93.265
Normalization	1.125	0.221	0.215	0.578	0.465	0.463	0.465	0.465
Grey correlation degree	0.512	0.425	0.362	0.625	0.415	0.389	0.465	0.512

Table 1 shows the performance of various supply chain collaboration activities (numbered *A* to *H*) under multiple indicators, including comprehensive material impact coefficient, rework time, rework cost, activity duration, subsequent activity duration, normalized values, and the grey correlation degree of each activity. Firstly, the comprehensive material impact coefficient shows the overall impact of various activities on supply chain efficiency. The coefficients for activities *D* and *H* are 0.215 and 0.225, respectively, in this indicator, demonstrating a high comprehensive material impact and a significant overall impact on supply chain management. Secondly, the normalized data of rework time and cost indicate that the rework time and cost of activity *D* are 0.032 and 0.042, respectively, both showing a significant impact. In particular, the rework cost of activity *E* is as high as 0.478, indicating its potential high cost risk. The normalized value of activity duration indicates that activity *D* has the longest duration (1.114), while the normalized value of the duration of subsequent activities shows that activity *A* has the longest duration of subsequent activities (1.125), suggesting that its sustained impact on subsequent activities is very significant. Finally, based on these indicators, the grey correlation degree calculated for activity *D* is 0.625, indicating its high correlation with other activities and significant impact on the entire supply chain collaboration project.

Table 2. Workload of supply chain collaboration activities and real-time buffer allocation

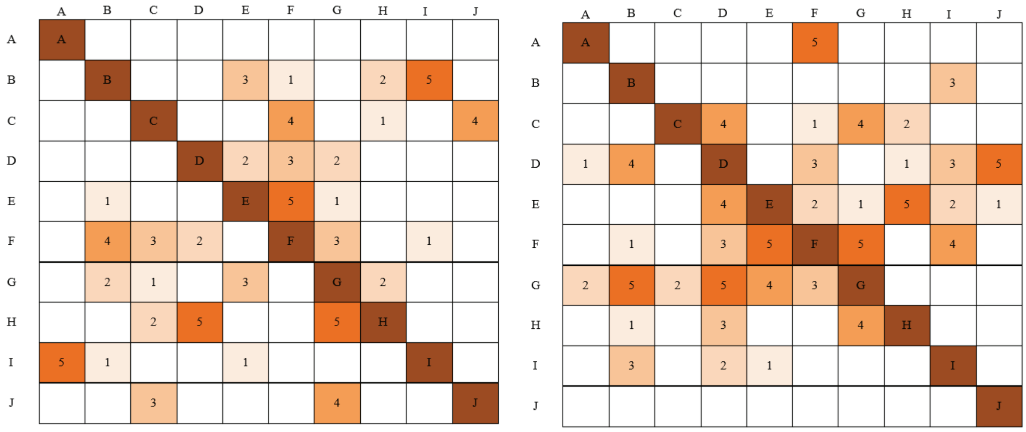
No.	Supply Chain Collaboration Activity	Planned Workload/ Person-Hour	Estimated Buffer Allocation/ Person-Hour	Monitoring Duration/ Person-Hour
1	Demand forecasting collaboration	465	68.95	532.26
2	Inventory management collaboration	556	87.25	635.89
3	Production plan collaboration	1236	223.56	1546.32
4	Transportation and distribution coordination	138	16.23	161.23
5	Order processing collaboration	312	31.56	342.56
6	Supplier management collaboration	115	12.54	121.36
7	Data sharing	278	31.26	326.25
8	Joint product development	3265	156.23	3215.14
9	Risk management collaboration	728	38.26	745.62
10	Promotion and marketing collaboration	462	22.32	465.21
11	Sustainable development collaboration		7.56	148.69
12	Other	278	13.56	289.32

According to the data in Table 2, the planned workload, estimated buffer allocation, and monitoring duration of each supply chain collaboration activity are as follows: the planned workload ranges from a minimum of 115 person-hours (supplier management collaboration) to a maximum of 3,265 person-hours (joint product development). Among them, the activity with the highest planned workload is joint product development (3,265 person-hours), while the activity with the lowest planned workload is supplier management collaboration (115 person-hours). In terms of buffer allocation, the buffer allocation amount for each activity also varies, with an estimated range of buffer allocation from 7.56 person-hours (sustainable development collaboration) to 223.56 person-hours (production plan collaboration). Overall, activities with larger planned workloads typically require greater buffer allocation, especially in production plan collaboration (223.56 person-hours) and joint product development (156.23 person-hours). The monitoring duration of these activities takes into account the time after buffer allocation, indicating that in the process of supply chain collaboration, it is necessary to address potential risks and delays by allocating buffer time reasonably. For example, the monitoring durations for inventory management collaboration and production plan collaboration are 635.89 person-hours and 1546.32 person-hours, respectively, indicating that they play an important role in the entire supply chain management and have high requirements for time management.

Table 3. Basic information of supply chain collaboration activities in supply chain collaboration projects

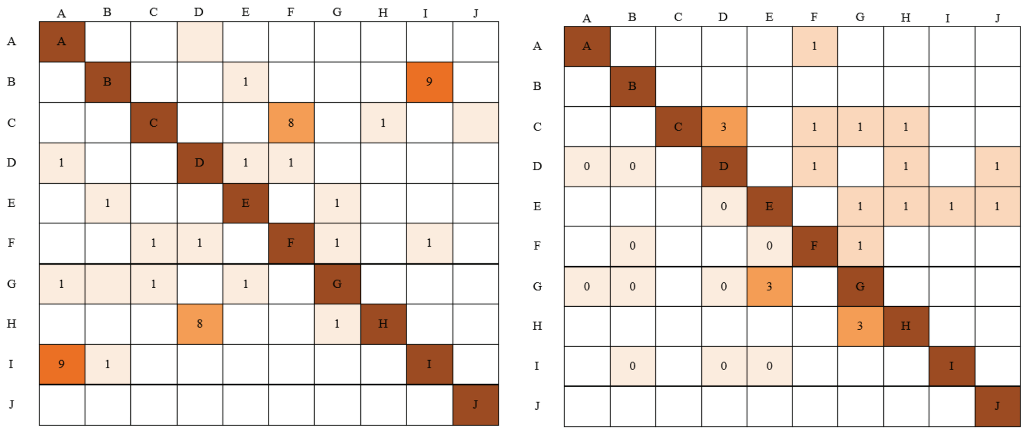
Supply Chain Collaboration Activity No.	Supply Chain Collaboration Activity ID	The Most Optimistic Time	The Most Likely Time	The Most Pessimistic Time	Required Quantity of Materials		
					Material 1	Material 2	Material 3
1	*A*	11	12	15	5	2	2
2	*B*	11	12	16	2	1	1
3	*C*	9	13	14	4	1	1
4	*D*	8	9	14	3	2	2
5	*E*	12	15	22	5	1	1
6	*F*	9	12	15	3	0	1
7	*G*	12	15	22	3	1	2
8	*H*	7	11	14	2	1	1
9	*I*	11	13	15	3	1	0
10	*J*	8	9	13	2	2	1
Material limit					7	2	3
Limitation degree of material projects					0.42	0.66	0.43

According to the data in Table 3, the basic information of supply chain collaboration activities shows the most optimistic time, the most likely time, the most pessimistic time, and the required quantity of materials for each activity. The most optimistic, most likely, and most pessimistic times provide three different time estimates for each activity, helping to predict the duration range of the activity. For example, the most optimistic time for activity *A* is 11 days, the most likely time is 12 days, and the most pessimistic time is 15 days, while the time range for activity *B* is 11 to 16 days. For the required quantity of materials, activities *A*, *B*, *C*, *D*, etc. require different material resources, with varying demands for materials 1, 2, and 3. It is worth noting that the table also lists the limit of each material and the degree of limitation for each material item. The limits for materials 1, 2, and 3 are 7, 2, and 3, respectively, while the degree of limitation for material projects is 0.42, 0.66, and 0.43, respectively. This indicates that material 2 has the highest degree of limitation in the project (0.66), which may have a greater impact on related supply chain collaboration activities.



a) Delay probability matrix **b) Delay impact intensity matrix**

Fig. 3. Probability matrix and rework impact intensity matrix of supply chain collaborative projects



a) Time factor matrix for mobile interaction information output **b) Time factor matrix for mobile interaction information input**

Fig. 4. Mobile information output and input time factor matrices for supply chain collaboration projects

In this experiment, the feedback delay and information transmission of various supply chain collaboration activities were analyzed by combining the timing and information flow of supply chain collaboration activities through Figures 3, 4, and 5, respectively. Figure 3 shows the probability matrix and rework impact intensity matrix of supply chain collaboration projects. By calculating the most optimistic, most likely, and most pessimistic times for each activity, as well as their interdependence, a probability model was constructed to clarify the completion time likelihood and risk level of each collaborative activity. Figure 4 further analyzes the output and input time factor matrices of mobile information in supply chain collaboration projects, revealing the time delay in the information flow transmission process. This figure indicates that when there is a delay in the input information of a certain activity, it directly affects the start time of its subsequent activities, thus forming a longer time lag chain. Finally, Figure 5 shows the delay factor matrix of the supply chain collaboration project, which mainly reflects the indirect delay impact between upstream and downstream activities within the range of $l = 3$ steps of mobile interaction information dissemination. The results indicate that as the interval between supply chain collaboration activities increases, although the number of indirect delays in information transmission increases, the actual impact of delays on subsequent activities gradually decreases. This indicates that mobile interaction technology can effectively control the impact of delayed delivery within a reasonable time frame.

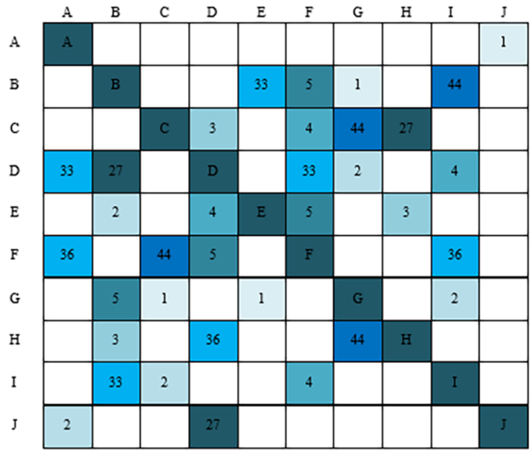


Fig. 5. Delay factor matrix for supply chain collaboration projects

7 CONCLUSION

This study delved into the strategy and practice of using mobile interactive technology to improve supply chain management, with a focus on analyzing four key research areas. By analyzing the influencing factors of supply chain materials, the direct impact of the supply status, degree of limitation, and demand on supply chain efficiency was revealed. For example, shortages, untimely supply, and highly restricted materials may lead to delays in supply chain collaboration activities, thereby affecting overall operational efficiency. This study discussed how mobile interaction technology can improve the transmission and feedback process of information flow in the supply chain. Through real-time information sharing and feedback mechanisms, mobile interaction technology can reduce information lag and improve the transparency and response speed of supply chain management, thereby reducing uncertainty and risks in the supply chain. This study conducted a detailed analysis of the sustained impact of mobile interaction technology on supply chain collaboration activities. It was found that this technology not only shortens information transmission time but also optimizes decision-making processes and improves collaboration efficiency, thereby promoting seamless integration between various links in the supply chain. Based on the application of mobile interaction technology, this study proposed a strategy for reasonably adjusting the priority of supply chain collaboration activities, emphasizing the use of dynamic scheduling and resource optimization configuration to ensure the smooth operation of key links and enhance the overall flexibility and adaptability of the supply chain.

This study has important practical value, especially in the current complex and ever-changing global supply chain environment, which can provide an effective technical solution. By applying mobile interactive technology, it is possible to improve supply chain efficiency while reducing delays, lowering costs, and enhancing responsiveness. Specifically, the results showed that through the rational application of mobile interaction technology, information flow in the supply chain can be made more efficient and collaboration activities more precise, thereby enhancing the supply chain's adaptability and market competitiveness. In addition, based on experimental data and case analysis, this study also demonstrated how to monitor in real time and dynamically adjust activities. However, this study also has certain limitations. Although this study explored the application and impact of mobile interaction technology, specific technical implementation and platform selection issues were not thoroughly discussed. How to combine theory with practice, especially the challenges faced in the technical implementation process, such as data security, privacy protection, and technology adaptation, still needs further research.

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