A Study on the Influencing Factors of Digital Transformation of Logistics Enterprises Utilizing the DEMATEL-ISM Model

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Abstract. In the era of the digital economy, the digital transformation of enterprises has emerged as an inevitable trend. As a pivotal industry leading the development of the national economy, the logistics sector urgently necessitates accelerating its digital transformation process to bolster its core competitiveness. Through a meticulous literature review and by incorporating valuable insights from relevant industry experts, this study identified twelve crucial influencing factors for the digital transformation of logistics enterprises. Subsequently, a DEMATEL-ISM model was constructed, leveraging the DEMATEL method to pinpoint the key influencing factors. The ISM model was then employed to unveil the intricate interrelationships among these factors, stratifying them into deep, transitional, and superficial levels, and presenting a comprehensive multi-level hierarchical structure diagram. Drawing from these insights, this study offers tailored countermeasures and strategic recommendations aimed at advancing the digital transformation of logistics enterprises, ultimately enhancing their operational efficiency and service quality, and effectively promoting the steady and robust progress of digital transformation efforts.

Keywords: digital transformation, logistics enterprise, influencing factors.

1 INTRODUCTION

The 20th National Congress of the Communist Party of China advocated "accelerating the growth of the digital economy and fostering its deep integration with the real economy"[1]. Subsequently, in 2023, the Central Committee of the Communist Party of China and the State Council outlined the "Overall Layout Plan for the Construction of Digital China," emphasizing its significance as a crucial driver of Chinese-style modernization in the digital era and a foundation for national competitive advantage [2]. The digital transformation of enterprises, particularly in the logistics sector, represents a necessary evolution driven by technological advancements and serves as a pivotal support for the construction of "Digital China." Nowadays, numerous logistics enterprises

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prioritize digital transformation as their primary development objective, with the government also actively promoting this transition.

Scholars have diverse views on enterprise digital transformation. Li et al.[3] emphasized internal business processes as a driver. Zhao et al.[4] identified R&D investment, human resource development, and management technology as key factors. Bai et al.[2] expanded on the impact of internal and external factors. Wang et al.[1] explored the combined effects of multiple conditions. Cichosz et al.[5] highlighted the role of employee engagement and training. Hu[6] underscored technological advancements in logistics. Li et al.[7] emphasized digital literacy in managers for enterprise transformation.

In summary, scholars have examined the influencing factors of digital transformation in logistics enterprises, yet a comprehensive analysis of their interconnections remains scarce. This study identifies key factors and employs the DEMATEL-ISM model to elucidate their intricate mechanisms and hierarchical relationships, offering insights for expedited digital transformation in the logistics sector.

2 ANALYSIS OF INFLUENCING FACTORS

Utilizing platforms such as CNKI and Wanfang Data, an extensive review of literature was conducted with the theme of "digital transformation of logistics enterprises." The existing research outcomes were analyzed, categorized, and summarized. Additionally, with input from relevant industry experts, the literature was screened and processed, resulting in the identification of 12 influencing factors that affect the digital transformation of logistics enterprises, as shown in Table 1.

Table 1. Explanation of influencing factors

number	Influencing factors	Explanation
S1	Digital technology development	The development of advanced digital technologies such as artificial intelligence
S2	Market competition	The use of digital technology by competitive enterprises will put pressure on enterprises, thus driving digital transformation
S3	Enterprise strategy	Enterprises adjust their strategic objectives and development directions according to changes in the market
S4	Enterprise innovation concept	Enterprises break the original logistics model and introduce digital technology thinking set
S5	Digital R&D investment	Invest a lot of research and development fund support to ensure the effective supply of resources
S6	Digital integration platform	Digital integration platform based on data and algorithm, supported by information foundation
S7	Supply chain digital construction	Use advanced technology and digital means to digitally transform and upgrade the supply chain
S8	Digital infrastructure development	The installation of digital infrastructure such as backbone network coverage and data security measures application
S9	Managerial digital literacy	The ability of managers to use digital tools to help businesses adapt to the digital environment
S10	Digital talent team building	Enterprises to the application of digital technology for employees, the operation of digital equipment and other training
S11	Financial support	Access to financing opportunities through financial support to ensure the financial strength of digital transformation
S12	Digital policy	The government's policy support for the development and application of digital technologies

3 CONSTRUCTION OF DEMATEL-ISM MODEL

The DEMATEL-ISM model utilizes the DEMATEL approach to explicitly determine the extent of influence of various factors on the system, as well as the interdependencies among these factors. Furthermore, the ISM technique is employed to establish a multi-level hierarchical structural model of system components, thus elucidating the underlying mechanisms of the interactions among the influencing factors[8].

3.1 Calculation of DEMATEL Parameters

(1) The direct influence matrix and comprehensive influence matrix were calculated. Twelve experts in relevant fields were invited to evaluate these 12 influencing factors. If more than half of the experts believed that factor S_i had a direct influence on factor S_j, a value of 1 was assigned; otherwise, a value of 0 was assigned ($S_{ij}=0$ when $i=j$). Based on the scoring results, the direct influence matrix A was obtained.

$$A=\begin{bmatrix} 0&1&0&0&0&1&0&0&0&0&0&0\\ 0&0&1&1&0&0&1&0&0&0&0&0\\ 0&0&0&0&0&0&1&0&0&1&0&0\\ 0&0&0&0&0&0&1&1&0&0&0&0\\ 0&0&0&0&0&1&1&0&0&0&0&0\\ 0&0&0&0&0&0&1&0&0&0&0&0\\ 0&0&0&0&0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&0&0&0&0&0&0\\ 0&0&0&0&0&0&1&0&0&0&0&0\\ 0&0&0&0&0&0&0&0&0&0&0&0\\ 0&0&1&1&1&1&1&0&0&1&0&0\\ 1&0&1&0&0&0&0&0&0&1&0&0 \end{bmatrix}$$

(2) The direct influence matrix was standardized. This involved normalizing the factors of matrix A by dividing each element by the maximum sum of elements in each row, resulting in the normalized direct influence matrix B. The formula for this process is as follows:

$$B=\frac{S_{ij}}{\max\left(\sum_{j=1}^{n} S_{ij}\right)} \tag{1}$$

(3) The comprehensive influence matrix was computed. Using MATLAB software, the normalized influence matrix B was multiplied by itself n times until all values converged towards zero. Subsequently, the sum of these n+1 matrices was calculated to obtain the comprehensive influence matrix C. The formula for this process is as follows (In the formula, I represents the identity matrix.):

$$C = \lim_{k \to \infty} B^k \left(B + B^2 + \cdots + B^k \right) = B(I - B)^{-1} \tag{2}$$

(4) The influence degree, affected degree, centrality, and causality of each factor were calculated. The centrality (Mi) and causality (Ni) of each factor were determined based on their influence degree (fi) and affected degree (ei). The results of the calculations are presented in Table 2. Based on Table 2, a cause-effect diagram of the influencing factors was constructed (see Fig. 1).

Table 2. Influence degree, affected degree, center degree and cause degree

number	Influence degree	affected degree	center degree	cause degree
S1	0.82	0.17	0.99	0.65
S2	0.58	0.19	0.78	0.39
S3	0.17	0.53	0.70	-0.37
S4	0.33	0.37	0.70	-0.03
S5	0.53	0.17	0.69	0.36
S6	0.17	0.56	0.72	-0.39
S7	0.00	1.50	1.50	-1.50
S8	0.00	0.39	0.39	-0.39
S9	0.17	0.19	0.36	-0.03
S10	0.00	0.56	0.56	-0.56
S11	1.20	0.00	1.20	1.20
S12	0.66	0.00	0.66	0.66

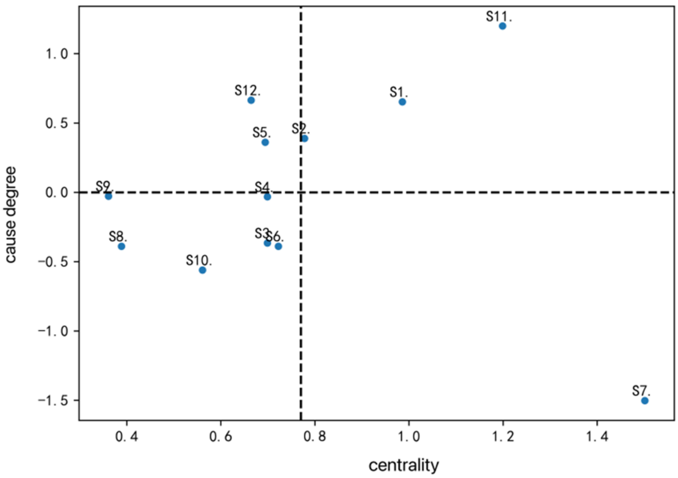

Fig. 1. Cause-effect diagram.

3.2 Calculation of Reachability Matrix

The comprehensive influence matrix B did not account for the self-influence of factors. Therefore, by adding the identity matrix I to B, the overall influence matrix H was obtained. The selection of the threshold value followed the principle of moderate node degree, and threshold values of 0.13, 0.15, 0.16, and 0.17 were set accordingly. Through comparative analysis, a threshold value of $\lambda = 0.16$ was determined to be suitable. Based on this, the reachability matrix K was derived.

$$K = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \end{bmatrix}$$

3.3 Classification of Influencing Factor Levels

By identifying the reachable set Ri and antecedent set Si for each influencing factor, and finding their intersection Ri∩Si, factors that satisfy the condition of Ri=Ri∩Si were determined as the first-level factors and subsequently removed. This process was repeated to obtain the influencing factors at each level. Through five iterations, the influencing factors were categorized into five levels, resulting in the following classification: L1={S7, S8, S10}, L2={S3, S4, S6, S9}, L3={S2, S5}, L4={S1, S11}, and L5={S12}. Based on the relationships among the various levels, a hierarchical structure diagram was constructed (see Fig. 2).

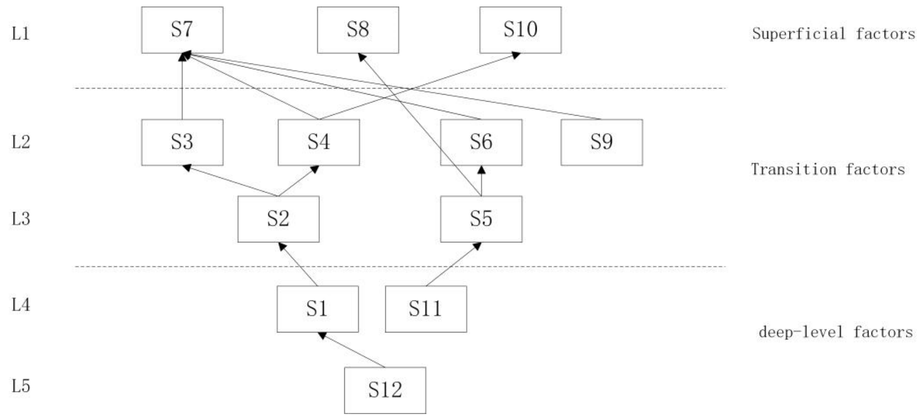

Fig. 2. Multi-level hierarchical structural model

3.4 Analysis of the Results

(1) Digital policies, technological advancements, and financial support serve as the deep-level factors driver of digital transformation in logistics enterprises. These deep-level factors impact transitional and superficial elements, shaping the entire process. Government policies and strategies optimize data factor markets and enhance digitization, while the expanding use of digital technologies propels the digital revolution in logistics[9]. Financial support catalyzes this transformation by enabling enterprises to secure funding for digital research and development.

(2) Market competition, corporate strategy, digital R&D investment, integration platforms, and managers' digital literacy functioned as transitional factors influenced by deep-level factors and shaping superficial aspects. As digitalization advances, leading logistics enterprises adopt advanced technologies to enhance efficiency and reduce costs, leading to strategic shifts and a focus on digital transformation. This choice significantly impacts the degree of digitalization, especially for small and medium-sized enterprises (SMEs), who must cultivate innovative mindsets and seek collaborations. Financial support boosts digital R&D investment, enabling the development of digital platforms and infrastructure. Managers' digital know-how and its integration into business processes drive digital transformation.

(3) The primary superficial factors driving the digital transformation of logistics enterprises include supply chain digitization, digital infrastructure development, and digital talent team construction. Integrating digital technologies into operational activities demands skilled digital talents[10]. By enhancing digital infrastructure and digitizing supply chains, enterprises can accelerate their informatization, digitization, and intelligentization, ultimately improving operational efficiency and facilitating digital transformation.

4 CONCLUSIONS

Through comprehensive literature research and consultation with experts, this paper identified the factors influencing the digital transformation of logistics enterprises and established a DEMATEL-ISM model to investigate their impact and interaction. Based on this analysis, a more intuitive understanding of these factors was gained, enabling more targeted recommendations for the digital transformation of logistics enterprises.Therefore, the following countermeasures and suggestions are proposed.

(1) Governments should enhance their support for digital policies, lower the financing barriers for enterprises, and thereby facilitate their digital transformation. Furthermore, governments at all levels should optimize the allocation of data resources, refine relevant laws and regulations, and cultivate a conducive institutional environment for the digital transformation of logistics enterprises. Additionally, increased incentives for external entities involved in enterprises' digital transformation, along with convenient financing mechanisms, could further stimulate the dynamism of logistics enterprises and expedite the process of digital transformation.

(2) Logistics enterprises must seize digital development opportunities, broaden financing channels, and integrate diverse resources. By leveraging digital policies and national incentives, they can transform these benefits into usable resources, thus advancing their digital transformation efforts. Given the substantial financial requirements for this process, especially for SMEs, actively seeking collaboration with larger logistics enterprises can enhance development potential and financial strength. Large logistics enterprises, in addition to domestic financing sources, should explore overseas financing opportunities to further broaden their funding avenues.

(3) The digital transformation of logistics enterprises is a protracted endeavor necessitating a well-defined digital strategy. Initially, defining the transformation's direction and strategic objectives, along with establishing a compatible organizational framework, is paramount. Subsequently, upgrading hardware and software facilities, accelerating digital infrastructure development, and leveraging technologies like AI, big data, and Internet of Things to establish a digital integration platform that integrates resources across modules are crucial. Finally, rigorous evaluation and validation of the transformation process are essential to ensure desired outcomes. Tailoring strategic decisions to the unique growth cycle and scale of individual logistics enterprises is imperative, with smaller enterprises opting for either early digital strategy implementation or transformation upon reaching operational maturity.

(4) Logistics enterprises must enhance the digital literacy of their managers and expedite the development of a digital talent pool. This can be accomplished through active digital skills training for management, improving their digital awareness and technological application abilities. Alternatively, hiring managers with strong digital literacy and involving them in digital transformation decisions is recommended. To fulfill the need for digital talent, enterprises can rely on both talent cultivation and recruitment. Large logistics enterprises can collaborate with universities and recruitment websites to attract high-caliber digital professionals. In contrast, small and medium-sized enterprises may find it more effective to identify and cultivate promising talent from within their ranks, enabling them to adapt to market shifts and strategic adjustments.

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