

# How leadership and digital capability drive operational performance in railway supply chains: the mediating role of agility

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## Abstract

**Purpose** – This study examines how leadership and digital capability influence supply chain agility and operational performance within railway supply chains in North America, with a focus on both direct and indirect pathways.

**Design/methodology/approach** – A quantitative research design was employed using survey data collected from 214 organizations operating within railway-centered supply chain networks across Canada, the United States and Mexico. The proposed model was tested using partial least squares structural equation modeling (PLS-SEM).

**Findings** – The results indicate that leadership plays a dual role in railway supply chain networks by directly enhancing supply chain agility and indirectly influencing agility through digital capability. Digital capability significantly improves both operational agility and performance within railway supply chain networks, while supply chain agility partially mediates the relationship between digital capability and performance.

**Practical implications** – The findings suggest that railway organizations should align leadership, digital investments and agile operational processes to improve responsiveness, coordination and operational performance in infrastructure-intensive environments.

**Originality/value** – This study extends existing literature by integrating leadership into capability-based models and demonstrating its direct and indirect influence on agility and performance in railway supply chains. This study highlights how performance in railway systems depends on the alignment of leadership, digital capability and agility within structurally constrained operational environments.

**Keywords** Leadership, Digital capability, Supply chain agility, Operational performance, Railway supply chains, Dynamic capabilities

**Paper type** Research article

## 1. Introduction

Digital transformation has become a central priority for organizations operating in complex and infrastructure-intensive environments such as railway supply chains (Browder, Dwyer, & Koch, 2024; Saari, Sinclair, Leshinsky, & Junnila, 2025). Increasing railway operational complexity, infrastructure capacity constraints and demand uncertainty require organizations to enhance both efficiency and responsiveness (Li, Miao, & Xu, 2024). In this context, digital capability has emerged as a critical enabler of real-time decision-making, predictive operational coordination and network-wide visibility across railway systems. Prior research indicates that digital technologies improve performance by enhancing information processing, integration and resource orchestration across supply chain activities (Imran, Shahzad, Butt, & Kantola, 2021; Truong, 2022). However, digital investments alone do not guarantee improved outcomes unless they are effectively embedded within organizational processes and supported

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by appropriate managerial and strategic mechanisms (Hamann-lohmer, Bendig, & Lasch, 2023; Yu, Zeng, & Zhang, 2025).

Supply chain agility has been widely recognized as a key capability that enables organizations to respond to disruptions, adapt to changing demand conditions and maintain operational performance. Agile railway supply chains are characterized by responsiveness, synchronized coordination and rapid operational decision-making, particularly in volatile and uncertain environments (Cantele, Russo, Kirchoff, & Valcozzena, 2023; Tse, Zhang, Akhtar, & Macbryde, 2016). Prior studies also suggest that agility plays a central role in linking operational capabilities to performance outcomes (Prater, Biehl, & Smith, 2001; Cui, Wang, Liu, & Cao, 2024). However, the mechanisms through which organizations develop and sustain agility remain insufficiently understood, especially in infrastructure-intensive systems such as railway networks where coordination complexity and regulatory constraints are significant.

Leadership plays a critical role in shaping organizational capabilities and enabling transformation initiatives. Leaders influence resource allocation, strategic priorities and organizational culture, all of which affect the development and deployment of digital technologies (Ludwikowska & Tworek, 2022; Karami, 2026). Prior research highlights that leadership is a key driver of innovation and capability development, particularly in technology-intensive environments (Lis, Glińska-neweś, & Kalińska, 2014). However, leadership may also directly influence railway operational capabilities such as agility by enabling faster decision-making, improving cross-functional coordination and facilitating adaptive responses to network disruptions and scheduling disturbances. Despite this potential, empirical research examining the direct relationship between leadership and supply chain agility remains limited and fragmented.

Drawing on the Resource-Based View (RBV) and Dynamic Capabilities perspective, this study argues that organizational performance is shaped by both strategic resources and the processes through which those resources are deployed (Wernerfelt, 1984; Barney, 1991; Teece, Pisano, & Shuen, 1997; Teece, 2007). Within RBV, resources contribute to sustained competitive advantage when they are valuable, rare, difficult to imitate and organizationally embedded (Barney, 1991). Digital capability represents a strategic organizational resource that enables information integration and operational coordination, while supply chain agility reflects a dynamic capability that enables organizations to respond effectively to environmental changes and operational disruptions (Christopher, 2000; Teece, 2007).

Despite increasing attention to digital transformation and supply chain agility, several important gaps remain in the literature. First, prior studies have primarily examined the indirect role of leadership through capability development, while overlooking its potential direct influence on agility. Second, existing research often considers digital capability and agility in isolation, rather than integrating them within a unified framework (Yu *et al.*, 2025). Third, empirical evidence from infrastructure-intensive sectors such as railway supply chains remains limited, despite their strategic importance and operational complexity. These gaps highlight the need for a more context-sensitive model that captures the multiple pathways linking leadership, capability development and performance outcomes within infrastructure-intensive railway systems.

Importantly, the railway context fundamentally alters how organizational capabilities operate and create value. Unlike conventional supply chains, railway systems are characterized by fixed infrastructure, tightly coupled network interdependencies, centralized control structures and strict safety and regulatory constraints. These characteristics significantly limit operational flexibility and reduce the effectiveness of isolated capability development. As a result, digital capability alone may not fully translate into improved performance unless it is operationalized through coordinated and system-wide adaptive responses. Similarly, leadership influence is constrained in real-time operations and must act through structured coordination mechanisms rather than discretionary flexibility. This suggests that capability deployment in railway systems is not independent or additive but

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sequential and interdependent, requiring alignment between leadership, digital capability and agility to achieve effective operational execution and performance outcomes. Therefore, this study proposes a constrained capability logic in which agility acts as the critical execution mechanism that enables digital capability to generate operational value within infrastructure-intensive environments. To address these gaps, this study develops and empirically tests a model that examines both direct and indirect relationships among leadership, digital capability, supply chain agility and operational performance. Specifically, the study investigates how leadership influences agility directly and indirectly through digital capability, and how these relationships contribute to performance outcomes. Using survey data from railway and logistics organizations in North America and applying Partial Least Squares Structural Equation Modeling (PLS-SEM), the study provides empirical evidence on the mechanisms linking leadership, capability development and operational performance.

This study contributes to the literature in several meaningful ways by offering a more integrated explanation of how organizational performance emerges in infrastructure-intensive supply chains. First, it moves beyond prior research that treats digital capability and supply chain agility as isolated constructs by explicitly modeling their sequential and complementary roles within a unified framework. In doing so, the study clarifies that digital capability alone does not directly translate into performance unless it is operationalized through agile processes, thereby refining the mechanism through which technological resources create value.

Second, this study extends the Dynamic Capabilities perspective by repositioning supply chain agility as an enacted capability rather than a latent organizational attribute. While prior research often conceptualizes agility as a general capability, this study indicates its role as a transformation mechanism that converts digital inputs into operational outcomes, particularly in highly coordinated and disruption-sensitive environments such as railway systems.

Third, the study introduces leadership as a dual path enabling mechanism that operates across both resource development and capability deployment. Rather than viewing leadership solely as an antecedent to digital transformation, the findings demonstrate that leadership directly shapes operational responsiveness while simultaneously influencing the development of digital capability. This dual role provides a more nuanced understanding of how managerial actions affect both the formation and execution of dynamic capabilities.

Finally, by focusing specifically on railway supply chains as an infrastructure-intensive and operationally constrained context, this study provides theoretical boundary conditions that highlight how capability development and deployment differ in highly constrained, interdependent and capital-intensive systems. This context-specific insight strengthens the generalizability of capability-based theories by demonstrating how their mechanisms operate under structural rigidity and coordination complexity.

Unlike general supply chains, railway systems operate under infrastructure rigidity, network interdependence, strict scheduling constraints and safety-critical operations. These characteristics fundamentally limit flexibility and require coordinated decision-making across interconnected subsystems such as signaling, rolling stock allocation and maintenance scheduling. Therefore, the development of agility in railway supply chains differs significantly from traditional logistics environments and requires the integration of digital monitoring systems, predictive analytics and centralized control mechanisms. This study explicitly incorporates these railway-specific operational constraints to extend capability-based theories into infrastructure-intensive transport systems. This study contributes by demonstrating that in infrastructure-intensive railway systems, capability effectiveness is constrained and sequential rather than independent and additive.

## **2. Literature review and hypotheses development**

### *2.1 Digital capability and operational performance*

Digital capability refers to an organization's ability to deploy, integrate and leverage digital technologies to enhance operational processes and decision-making (Permana, Poerwoko,

Widyastuti, & Rachbini, 2019). It includes data analytics, system integration and real-time monitoring capabilities that support coordination across supply chain activities. Prior research suggests that digital capability improves performance by enhancing information visibility, reducing uncertainty and enabling more efficient resource allocation (Imran *et al.*, 2021; Truong, 2022). In infrastructure-intensive environments such as railway systems, digital capability plays a critical role in optimizing scheduling, improving asset utilization and enabling predictive maintenance, all of which contribute to improved operational efficiency and service reliability.

From the perspective of the Resource-Based View (RBV), digital capability can be considered a strategic organizational resource that contributes to sustained competitive advantage when it is valuable, difficult to imitate and effectively embedded within organizational processes (Wernerfelt, 1984; Barney, 1991). These capabilities enhance operational effectiveness by reducing delays, improving coordination and increasing responsiveness to changing conditions. Therefore, digital capability is expected to have a direct and positive effect on operational performance.

*H1. Digital capability positively influences operational performance.*

### *2.2 Digital capability and supply chain agility*

Supply chain agility reflects an organization's ability to respond quickly and effectively to changes in demand, supply disruptions and environmental uncertainty. Agile supply chains are characterized by flexibility, responsiveness, speed and adaptive coordination across interconnected operational activities, which are critical in dynamic and complex operational environments (Christopher, 2000). Digital capability plays a central role in enabling agility by providing timely information, enhancing communication and facilitating coordination across supply chain activities (Tse *et al.*, 2016; Cantele *et al.*, 2023). Digital technologies enable organizations to monitor operations in real time, identify disruptions and adjust processes, accordingly, thereby improving responsiveness.

From a Dynamic Capabilities perspective, digital capability enhances the organization's ability to sense, coordinate and respond to environmental changes (Manzoor *et al.*, 2022; Teece, 2007). In railway supply chains, where operations are tightly interconnected and disruptions can have cascading effects, digital capability enables faster and more effective responses to unexpected events. By improving information flow and coordination, digital capability supports adaptive decision-making and enhances operational flexibility. These characteristics are essential for developing supply chain agility in complex and uncertain environments.

*H2. Digital capability positively influences supply chain agility.*

### *2.3 Supply chain agility and operational performance*

Supply chain agility has been widely recognized as a key determinant of operational performance in dynamic environments. Agile organizations are better able to respond to disruptions, adjust to demand fluctuations and maintain service continuity (Manzoor *et al.*, 2022). Prior research indicates that agility improves performance by enhancing flexibility, reducing lead times and enabling rapid responses to changing conditions (Prater *et al.*, 2001; Cui *et al.*, 2024). These capabilities allow railway organizations to minimize the negative impact of operational disruptions, scheduling delays and infrastructure-related interruptions while maintaining operational efficiency.

In railway systems, agility is particularly important due to the complexity of infrastructure, interdependence of operations and high cost of delays (Cantele *et al.*, 2023). Agile supply chains enable organizations to adjust schedules, allocate resources efficiently and maintain reliability under uncertain conditions. From a Dynamic Capabilities perspective, agility

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reflects the organization's ability to reconfigure and redeploy resources in response to environmental changes. This capability directly contributes to improved operational performance by enhancing responsiveness and reducing inefficiencies.

*H3.* Supply chain agility positively influences operational performance.

#### *2.4 Leadership and digital capability*

Leadership in this study is conceptualized as a coordination-oriented managerial capability that enables alignment between digital initiatives and operational processes within complex railway systems (Abourobah, Mashat, & Salam, 2023). Rather than focusing on a specific leadership style (e.g. transformational or transactional), this study adopts a functional perspective in which leadership reflects managerial actions related to strategic direction, cross-functional coordination and support for technology-driven change (Cheng, Li, Wu, Ye, & Jiang, 2024; Durman, Iyiola, Alzubi, & Aljuhmani, 2025). This conceptualization is consistent with capability-based views of management, where leadership facilitates the orchestration and deployment of organizational resources (Albannai, Raziq, Malik, Scott-kennel, & Igoe, 2025; Chatterjee, Chaudhuri, Vrontis, & Giovando, 2023). In infrastructure-intensive environments such as railway supply chains, leadership is particularly critical for ensuring synchronization across interdependent operational units, where decisions related to scheduling, maintenance and traffic control must be aligned with digital systems and real-time information flows.

From a Resource-Based View perspective, leadership can be understood as an intangible organizational capability that enables the effective deployment of technological resources (Chatterjee *et al.*, 2023). Leadership facilitates the orchestration of resources by promoting coordination, reducing resistance to change and supporting learning processes associated with digital transformation (Hamann-lohmer *et al.*, 2023; Yu *et al.*, 2025). In this sense, leadership does not merely precede capability development but actively shapes how digital technologies are integrated into operational processes and decision-making routines.

In railway supply chains, where operations are highly interconnected and disruptions can have cascading effects, leadership plays a critical role in enabling the adoption and effective use of digital systems such as real-time monitoring, predictive analytics and integrated scheduling platforms. By providing strategic direction and fostering collaboration across functional boundaries, leadership supports the development of digital capability that enhances coordination and responsiveness. Therefore, leadership is expected to positively influence digital capability.

*H4.* Leadership positively influences digital capability.

#### *2.5 Leadership and supply chain agility*

In addition to its role in capability development, leadership may also directly influence operational capabilities such as supply chain agility (Schweitzer, 2014). Leaders facilitate coordination, enable faster decision-making and promote responsiveness across organizational units, all of which are essential for managing disruptions (Turner, Baker, Schroeder, Johnson, & Chung, 2018). Prior research suggests that leadership enhances organizational responsiveness by encouraging flexibility, empowering employees and supporting proactive problem-solving (Prabhu & Srivastava, 2023; Leana-morales & Cuevas-vargas, 2024).

In railway systems, where operational processes are tightly interconnected and disruptions can propagate quickly, leadership plays a critical role in enabling agility. Leaders can improve coordination across operational functions, reduce delays in disruption-response decision-making and support adaptive responses to signaling failures, scheduling disruptions and operational bottlenecks. These actions enhance the organization's ability to respond effectively to disruptions and maintain operational continuity. Therefore, leadership is

expected to directly influence supply chain agility in addition to its indirect effect through digital capability.

*H5.* Leadership positively influences supply chain agility.

### *2.6 The mediating role of supply chain agility*

Supply chain agility is increasingly recognized as a critical mechanism through which organizational capabilities are translated into performance outcomes (Cantele *et al.*, 2023). While digital capability enhances information processing, system integration and operational visibility, its direct impact on performance depends on the organization's ability to act upon this information in a timely and coordinated manner (Leana-morales & Cuevas-vargas, 2024). Prior research suggests that agility enables organizations to convert technological and informational resources into operational outcomes by facilitating rapid and effective responses to environmental changes (Tse *et al.*, 2016; Cantele *et al.*, 2023).

From a Dynamic Capabilities perspective, agility reflects the organization's ability to reconfigure and coordinate interdependent processes in response to changing conditions (Manzoor *et al.*, 2022; Eisenhardt & Martin, 2017). In railway supply chains, digital capability primarily provides enhanced visibility through real-time monitoring systems, predictive maintenance tools and integrated scheduling platforms. However, due to infrastructure rigidity, network interdependence and strict operational constraints, the availability of information alone does not automatically lead to improved performance. Railway operations require synchronized decision-making across multiple interconnected subsystems, where delays or disruptions in one part of the network can propagate rapidly across the entire system.

As a result, digital capability creates the informational foundation for improved decision-making, but it does not guarantee effective execution. Supply chain agility represents the execution mechanism that enables organizations to translate digital insights into coordinated operational actions, such as dynamic rescheduling, real-time resource allocation and disruption recovery. This distinction is particularly important in railway systems, where operational responsiveness depends more on coordination efficiency than on physical flexibility. Therefore, digital capability influences performance both directly and indirectly, with agility serving as the critical mechanism that determines whether and how digital resources are transformed into operational outcomes.

*H6.* Supply chain agility mediates the relationship between digital capability and operational performance.

### *2.7 Integrated model explanation*

The proposed model integrates direct and indirect relationships among leadership, digital capability, supply chain agility and operational performance. Leadership is expected to influence digital capability by shaping strategic priorities and enabling technology adoption, while also directly enhancing supply chain agility by improving coordination and responsiveness. Digital capability contributes to performance both directly and indirectly through its effect on agility. Supply chain agility, in turn, plays a central role in translating capabilities into operational outcomes.

In railway systems, digital capability manifests through technologies such as real-time traffic management systems, predictive maintenance platforms, automated scheduling and network-wide coordination tools. These technologies enable visibility across interconnected operations but require strong leadership coordination to translate information into timely operational actions. Similarly, supply chain agility in railway contexts is constrained by fixed infrastructure and regulatory requirements, making it dependent on coordination efficiency rather than pure flexibility. Accordingly, the proposed model is interpreted within the unique structural constraints of railway networks rather than generic supply chain environments.

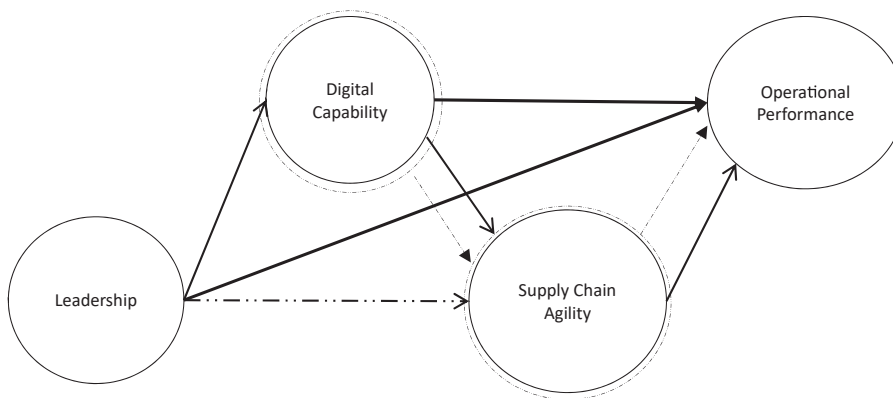
Figure 1 presents the conceptual framework of the study, illustrating the direct and indirect relationships among leadership, digital capability, supply chain agility and operational performance. The model highlights the dual role of leadership and the mediating role of agility in linking digital capability to performance outcomes.

### 3. Methodology

#### 3.1 Research design and sample

The study adopts a quantitative research design to examine the relationships among leadership, digital capability, supply chain agility and operational performance within North American railway freight and operational supply chain networks. Data were collected using a structured survey administered to organizations operating in railway and logistics sectors across Canada, the United States and Mexico. A purposive sampling approach was employed to target respondents with direct operational and managerial expertise related to railway supply chain coordination, infrastructure management and digitally enabled operational processes. A total of 214 valid responses were obtained, which exceeds recommended thresholds for Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis (Hair, Risher, Sarstedt, & Ringle, 2019). The demographic and organizational characteristics of the sample are summarized in Table 1.

The inclusion of multiple organizational types reflects the operational structure of contemporary railway supply chains, which function as integrated and highly interdependent transport ecosystems rather than isolated organizational entities. Railway operators remain the central actors within the network and represent the largest proportion of the sample (38.3%). However, operational performance within railway systems also depends heavily on coordination with infrastructure and maintenance firms, logistics providers and integrated supply chain service organizations that support scheduling, freight coordination, terminal operations, maintenance activities and intermodal connectivity. Unlike conventional supply chains characterized by relatively modular relationships, railway systems operate through tightly coupled operational sequences in which disruptions within one organizational segment can rapidly propagate across interconnected network activities. Consequently, real-time coordination, information sharing and synchronized decision-making across multiple organizational actors are essential for maintaining operational continuity and performance. Therefore, the inclusion of multiple organizational roles does not represent conceptual heterogeneity but rather reflects the systemic and networked nature of railway supply chains and improves the ecological validity of the study.



**Figure 1.** Conceptual framework of leadership, digital capability, and supply chain agility. **Source:** Author's own creation

**Table 1.** Sample characteristics ( $N = 214$ )

Category	<i>n</i>	%
<i>Country</i>		
Canada	73	34.1
United States	88	41.1
Mexico	53	24.8
<i>Industry type</i>		
Railway operators	82	38.3
Logistics providers	67	31.3
Infrastructure/maintenance firms	41	19.2
Railway-integrated supply chain services	24	11.2
<i>Respondent role</i>		
Operations managers	56	26.2
Supply chain managers	48	22.4
IT/Digital managers	39	18.2
Senior executives	34	15.9
Supervisors/technical staff	37	17.3
<i>Work experience</i>		
Less than 5 years	42	19.6
5–10 years	78	36.4
More than 10 years	94	44.0
<i>Firm size</i>		
Small (<50 employees)	26	12.1
Medium (50–249 employees)	58	27.1
Large (250+ employees)	130	60.7
<b>Source(s):</b> Author's own creation		

### 3.2 Measurement development

All constructs were measured using multi-item scales adapted from established studies and contextualized to reflect railway operational environments. Specifically, item wording was modified to capture railway-specific operational characteristics such as real-time traffic coordination, signaling dependencies, infrastructure constraints, maintenance scheduling and interdependent network operations. This contextualization ensures that the constructs accurately represent capability development and operational responsiveness within railway supply chains rather than generic logistics settings. Leadership was operationalized using items reflecting strategic direction, coordination and decision-making support adapted from [Ludwikowska and Tworek \(2022\)](#) and contextualized for railway operational environments. Digital capability was measured using items capturing system integration, analytics capability and real-time information processing, based on [Cheng et al. \(2024\)](#) and [\(Truong, 2022\)](#). Supply chain agility was measured using indicators related to responsiveness, flexibility and adaptation to disruptions derived from [Cantele et al. \(2023\)](#) and [Tse et al. \(2016\)](#). Operational performance was assessed using measures of efficiency, reliability and service quality adapted from [Cui et al. \(2024\)](#). The measurement constructs and their corresponding sources are presented in [Table 2](#).

All items were measured on a five-point Likert scale ranging from strongly disagree to strongly agree. The questionnaire development followed a rigorous process including scale adaptation, expert validation and pilot testing with industry professionals to ensure clarity and contextual relevance. Minor adjustments were made based on feedback to improve wording and reduce ambiguity. This process ensured strong content validity and alignment between measurement items and the operational characteristics of railway supply chain environments.

**Table 2.** Measurement constructs, sources, and railway contextualization

Construct	Source
Leadership	Oke <i>et al.</i> (2009)
Digital Capability	Rai <i>et al.</i> (2006), Cheng <i>et al.</i> (2024)
Supply Chain Agility	Gligor <i>et al.</i> (2013), Swafford <i>et al.</i> (2006)
Operational Performance	Blome <i>et al.</i> (2013)
<b>Source(s):</b> Author's own creation	

A full list of measurement items and their railway-specific contextual adaptations is provided in [Appendix A](#). The adaptation ensures alignment between established measurement scales and railway-specific operational contexts.

### 3.3 Data analysis technique

The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software. PLS-SEM was selected due to its suitability for complex models that include multiple relationships, mediation effects and predictive objectives. It is particularly appropriate for studies with moderate sample sizes and non-normal data distributions (Hair *et al.*, 2019). The analysis followed a two-step approach, beginning with the assessment of the measurement model and followed by evaluation of the structural model.

Bootstrapping with 5,000 resamples was applied to assess the statistical significance of path coefficients. Bias-corrected confidence intervals were used to improve estimation accuracy. The analysis also incorporated predictive relevance ( $Q^2$ ) and out-of-sample prediction using PLSpredict to evaluate model performance beyond in-sample fit. This approach ensures robust and reliable estimation of both direct and indirect relationships in the proposed model.

### 3.4 Measurement model assessment

The measurement model was evaluated in terms of reliability and validity to ensure the robustness of the constructs. Internal consistency reliability was assessed using Cronbach's alpha and composite reliability, with values exceeding the recommended threshold of 0.70 (Hair *et al.*, 2019). Convergent validity was evaluated using average variance extracted (AVE), with values above 0.50 indicating that the constructs explain a sufficient proportion of variance in their indicators. Indicator loadings were examined to confirm that each item loads strongly on its respective construct.

Discriminant validity was assessed using the Fornell–Larcker criterion and the Heterotrait–Monotrait (HTMT) ratio (Fornell & Larcker, 1981; Henseler, Ringle, & Sarstedt, 2015). HTMT values below 0.85 indicate that constructs are empirically distinct. These procedures ensure that the measurement model is reliable, valid and appropriate for structural model analysis, providing a solid foundation for testing the proposed hypotheses.

### 3.5 Structural model assessment

The structural model was assessed by examining path coefficients, significance levels, coefficient of determination ( $R^2$ ) and effect sizes ( $f^2$ ). Multicollinearity was evaluated using variance inflation factor (VIF) values, which were below the recommended threshold of 3.3, indicating no collinearity concerns. Predictive relevance was assessed using  $Q^2$  values, with values greater than zero indicating acceptable predictive capability of the model.

Mediation analysis was conducted to examine the indirect effect of digital capability on operational performance through supply chain agility. Control variables, including firm size and respondent role, were incorporated to account for potential confounding effects. In

addition, multi-group analysis was performed to assess whether structural relationships differ across countries, ensuring the robustness and generalizability of the findings across North American contexts.

### 3.6 Common method bias and ethical considerations

Several procedural and statistical measures were implemented to address potential common method bias (CMB). Procedurally, respondents were assured of anonymity and confidentiality, and questionnaire items were carefully designed to minimize ambiguity, reduce evaluation apprehension and limit social desirability bias. In addition, construct items were separated conceptually within the questionnaire structure to reduce consistency motives and common response patterns. Statistically, Harman's single-factor test, marker variable procedures and the full collinearity variance inflation factor (VIF) approach were applied to assess the presence of common method variance (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Kock, 2015). The Harman single-factor test indicated that the first factor accounted for 34.2% of the total variance, which is below the commonly accepted threshold of 50%, suggesting that common method bias is unlikely to substantially affect the findings. In addition, all full collinearity VIF values were below the recommended threshold of 3.3, further indicating that common method variance is not a serious concern in this study.

Ethical considerations were strictly followed throughout the research process. Participation was voluntary, and informed consent was obtained from all respondents prior to data collection. Data were handled in accordance with ethical research standards, ensuring confidentiality and protection of participants' information. These measures enhance the credibility, transparency and integrity of the study. In addition, common method bias was further assessed using the full collinearity variance inflation factor (VIF) approach (Kock, 2015). All VIF values were below the recommended threshold of 3.3, indicating that common method bias is unlikely to be a serious concern in this study. Collectively, these procedural and statistical assessments provide a robust evaluation of potential method bias beyond reliance on a single diagnostic technique.

## 4. Results

### 4.1 Descriptive statistics and preliminary analysis

The analysis is based on 214 valid responses collected from railway and logistics organizations across North America. Prior to hypothesis testing, the dataset was screened for missing values, outliers and distributional properties. No significant missing data were detected, and no extreme outliers were identified. Skewness and kurtosis values were within acceptable ranges, indicating no serious deviations from normality. Although PLS-SEM does not require strict normality assumptions, these checks support the robustness of the dataset and the validity of subsequent analysis. Descriptive statistics and correlations among the constructs are presented in Table 3.

**Table 3.** Descriptive statistics and correlations

Construct	Mean	SD	1	2	3	4
1. Leadership	5.41	0.89	1.00			
2. Digital Capability	5.33	0.92	0.59**	1.00		
3. SC Agility	5.27	0.87	0.52**	0.57**	1.00	
4. Performance	5.29	0.90	0.47**	0.55**	0.46**	1.00

**Note(s):** \*\* $p < 0.001$

**Source(s):** Author's own creation

The results indicate moderate and statistically significant correlations among all constructs, providing preliminary support for the proposed railway capability framework. Variance inflation factor (VIF) values were below 3.3, indicating no multicollinearity concerns. These findings confirm that the dataset is appropriate for structural model estimation and hypothesis testing, providing a reliable foundation for evaluating the proposed conceptual framework.

#### 4.2 Measurement model results

The measurement model was assessed for reliability and validity following established guidelines in Partial Least Squares Structural Equation Modeling (PLS-SEM) (Hair *et al.*, 2019; Henseler *et al.*, 2015). Internal consistency reliability was evaluated using Cronbach's alpha and composite reliability (CR). As reported in Table 4, all CR values exceed the recommended threshold of 0.70, indicating satisfactory internal consistency (Hair *et al.*, 2019).

Convergent validity was assessed using average variance extracted (AVE). All constructs exhibit AVE values above the threshold of 0.50, confirming that the indicators explain more than half of the variance of their respective constructs (Fornell & Larcker, 1981; Hair *et al.*, 2019). In addition, all standardized indicator loadings exceed 0.70 and are statistically significant, demonstrating strong indicator reliability and supporting the adequacy of the measurement items.

Discriminant validity was evaluated using three complementary approaches. First, the Fornell–Larcker criterion was satisfied, as the square root of AVE for each construct is greater than its correlations with other constructs (Fornell & Larcker, 1981). Second, the Heterotrait–Monotrait ratio of correlations (HTMT) was examined. Based on the inter-construct correlations reported in Table 3, HTMT values range from 0.42 to 0.78, which are below the conservative threshold of 0.85, confirming discriminant validity (Henseler *et al.*, 2015). Third, cross-loading analysis indicates that each indicator loads higher on its associated construct than on any other construct, further supporting construct distinctiveness.

Overall, the results demonstrate that the measurement model satisfies all recommended reliability and validity criteria. The constructs are internally consistent, exhibit strong convergent validity and are empirically distinct, thereby providing a robust basis for subsequent structural model analysis. Detailed measurement model results are provided in Appendix B.

#### 4.3 Structural model results

The structural model was evaluated using bias-corrected bootstrapping with 5,000 resamples. The results, summarized in Table 5, indicate that all hypothesized relationships are statistically significant. Leadership positively influences digital capability ( $\beta = 0.61$ ,  $SE = 0.067$ ,  $t = 9.12$ ,  $p < 0.001$ , 95% CI [0.48, 0.73]), supporting H4. Leadership also directly affects supply chain agility ( $\beta = 0.32$ ,  $SE = 0.081$ ,  $t = 3.95$ ,  $p < 0.01$ , 95% CI [0.16, 0.47]), supporting H5.

**Table 4.** Measurement model assessment

Construct	CR	AVE
Leadership	0.88	0.59
Digital Capability	0.90	0.62
SC Agility	0.89	0.60
Performance	0.91	0.64

**Source(s):** Author's own creation

**Table 5.** Structural model results with standardized coefficients and confidence intervals

Hypothesis	Path	$\beta$	SE	$t$	$p$	95% CI
H1	Digital Capability → Performance	0.29	0.093	3.12	<0.01	[0.11, 0.46]
H2	Digital Capability → SC Agility	0.58	0.069	8.45	<0.001	[0.44, 0.71]
H3	SC Agility → Performance	0.47	0.067	6.98	<0.001	[0.33, 0.60]
H4	Leadership → Digital Capability	0.61	0.067	9.12	<0.001	[0.48, 0.73]
H5	Leadership → SC Agility	0.32	0.081	3.95	<0.01	[0.16, 0.47]

**Source(s):** Author's own creation

Digital capability positively influences supply chain agility ( $\beta = 0.58$ , SE = 0.069,  $t = 8.45$ ,  $p < 0.001$ , 95% CI [0.44, 0.71]) and operational performance ( $\beta = 0.29$ , SE = 0.093,  $t = 3.12$ ,  $p < 0.01$ , 95% CI [0.11, 0.46]), supporting H2 and H1. Supply chain agility also positively affects performance ( $\beta = 0.47$ , SE = 0.067,  $t = 6.98$ ,  $p < 0.001$ , 95% CI [0.33, 0.60]), supporting H3. The model explains a substantial proportion of variance, with  $R^2$  values of 0.37 (digital capability), 0.41 (supply chain agility) and 0.46 (performance). Model fit is acceptable, with the Standardized Root Mean Square Residual (SRMR) equal to 0.067. The SRMR value of 0.067 is below the recommended threshold of 0.08, indicating an acceptable model fit. The inner VIF values ranged from 1.21 to 2.48, indicating no multicollinearity concerns.

#### 4.4 Effect size and predictive relevance

Effect size ( $f^2$ ) values indicate that leadership has a medium effect on digital capability ( $f^2 = 0.32$ ), while digital capability has a medium effect on supply chain agility ( $f^2 = 0.29$ ) and a small-to-medium effect on operational performance ( $f^2 = 0.12$ ). Supply chain agility indicates a medium effect on operational performance ( $f^2 = 0.25$ ). These results indicate that the relationships are not only statistically significant but also meaningful in practical terms. Effect size results are summarized in Table 6.

Predictive relevance was supported by Stone–Geisser's  $Q^2$  values of 0.21 for digital capability, 0.18 for supply chain agility and 0.24 for operational performance, indicating acceptable predictive capability. The PLSPredict procedure indicates that 9 out of 10 indicators exhibit lower RMSE values compared to linear model benchmarks, confirming satisfactory out-of-sample predictive performance.

#### 4.5 Mediation analysis

The mediating role of supply chain agility was assessed using bootstrapping procedures. The indirect effect of digital capability on operational performance through supply chain agility is positive and statistically significant ( $\beta = 0.27$ ,  $p < 0.001$ , 95% CI [0.18, 0.38]), supporting H6. The direct effect of digital capability on performance remains significant ( $\beta = 0.29$ ,  $p < 0.01$ ), indicating partial mediation. This pattern reflects complementary partial mediation, as both the

**Table 6.** Effect size assessment ( $f^2$ )

Path	$f^2$	Effect
Leadership → Digital Capability	0.32	Medium
Digital Capability → SC Agility	0.29	Medium
SC Agility → Performance	0.25	Medium
Digital Capability → Performance	0.12	Small–Medium

**Source(s):** Author's own creation

direct and indirect effects are statistically significant and operate in the same direction, consistent with the classification proposed by Zhao, Lynch, and Chen (2010).

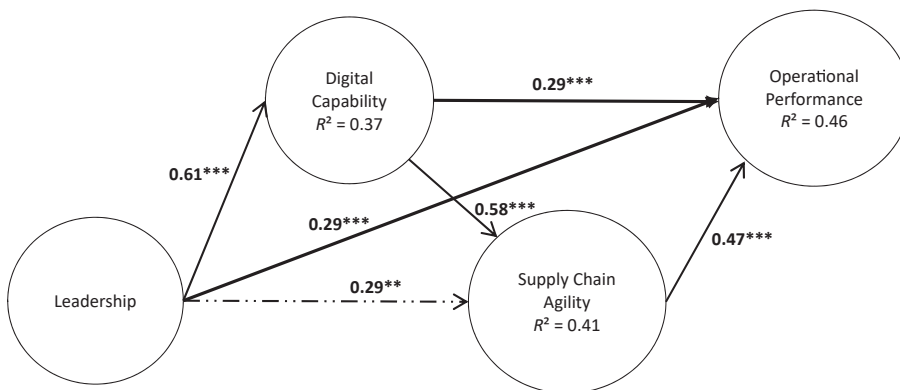
The findings suggest that digital capability improves operational performance through multiple mechanisms simultaneously. Indirectly, digital capability enhances agility by improving operational visibility, coordination and responsiveness across interconnected railway activities. At the same time, digital capability may also generate direct operational efficiencies independent of agility, such as improved scheduling accuracy, predictive maintenance optimization, energy efficiency, asset utilization and reduced operational delays. Consequently, while supply chain agility represents a critical execution mechanism through which digital capability creates operational value, additional direct efficiency gains also contribute to performance improvement within railway systems.

The total effect of digital capability on performance is  $\beta = 0.56$ , which equals the sum of the direct and indirect effects. The Variance Accounted For (VAF) value is approximately 48% indicating substantial but not full mediation. These findings demonstrate that digital capability influences performance both directly and indirectly through supply chain agility, highlighting that operational performance in railway systems depends not only on technological resources themselves but also on the organization’s ability to convert digital insights into coordinated operational execution.

#### 4.6 Robustness checks and model visualization

Robustness checks were conducted to assess the stability of the findings. Control variables, including firm size and respondent role, were incorporated into the model and found to have no significant effects ( $p > 0.10$ ). Multi-group analysis using Partial Least Squares Multi-Group Analysis (PLS-MGA) indicated no significant differences across Canada, the United States and Mexico, suggesting that the model is stable across different national contexts.

Figure 2 presents the structural model with standardized path coefficients and  $R^2$  values. The visual representation is associated with the strength and direction of the relationships and highlights both the direct and indirect pathways through which leadership and digital capability influence operational performance.



**Figure 2.** Structural model results with standardized path coefficients and  $R^2$  Values. **Note:** Standardized path coefficients are reported. \*\*\* $p < 0.001$ , \*\* $p < 0.01$ . **Source:** Author’s own creation

## 5. Discussion

### 5.1 Key findings

This study examines how leadership and digital capability influence supply chain agility and operational performance within railway supply chains in North America. The findings demonstrate that leadership plays a dual role by both enabling digital capability and directly enhancing supply chain agility. Digital capability, in turn, significantly improves both agility and operational performance, while supply chain agility acts as a key mechanism translating capabilities into performance outcomes. These results indicate that operational performance is not driven by isolated factors but by an interconnected system of leadership, technological capability and adaptive processes.

Importantly, the results show that supply chain agility partially mediates the relationship between digital capability and performance, confirming that digital investments alone are insufficient unless they are effectively embedded within agile operational processes. This highlights that technological investments alone may not generate meaningful operational improvements unless they are supported by agile organizational processes and coordinated execution capabilities.

### 5.2 Theoretical contributions

This study makes several important theoretical contributions by addressing important gaps in the existing literature and advancing capability-based explanations of performance in infrastructure-intensive supply chains.

First, the study refines prevailing Resource-Based View explanations by demonstrating that digital capability does not automatically translate into performance outcomes in infrastructure-intensive environments. Prior research has largely treated digital capability as a standalone strategic resource that improves efficiency and coordination. However, this perspective overlooks the operational mechanisms through which value is realized. The findings demonstrate that although digital capability contributes directly to operational efficiency, its broader performance impact is substantially strengthened when operationalized through supply chain agility, thereby refining the resource–performance linkage and clarifying the conditions under which digital investments create value.

Second, this study extends the Dynamic Capabilities perspective by positioning supply chain agility as an enacted and constrained capability rather than a generic organizational attribute. Existing literature often conceptualizes agility as a broadly flexible organizational capability that enables rapid adaptation across operational settings. However, the findings of this study suggest that agility operates differently within infrastructure-intensive railway systems characterized by fixed track geometry, centralized traffic control, signaling dependencies and tightly interconnected operational sequences. In such environments, disruptions occurring at a single operational point, such as a signaling failure, rolling stock delay or maintenance interruption, can propagate sequentially across interconnected network activities and rapidly affect broader system performance. As a result, capability deployment within railway systems is not independent or additive but sequential and interdependent. Leadership coordination enables the development of digital capability, digital capability enhances operational visibility and information synchronization, and supply chain agility functions as the execution mechanism through which coordinated responses are operationalized across the network. Under these structural conditions, agility depends less on physical flexibility and more on coordination efficiency, synchronized decision-making and rapid operational alignment across interconnected subsystems. This constrained capability logic provides important boundary conditions for Dynamic Capabilities theory by demonstrating how capability effectiveness is shaped by infrastructure rigidity, operational sequentiality and system-wide coordination requirements.

Third, the study advances the role of leadership by introducing it as a dual path enabling mechanism that operates across both capability development and operational execution. While

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prior studies primarily conceptualize leadership as an antecedent to technological adoption, the findings demonstrate that leadership also directly influences operational responsiveness independent of digital capability. This dual-path effect provides a more nuanced understanding of how managerial actions simultaneously shape resource formation and capability activation.

Finally, by focusing on railway supply chains, this study contributes to the literature by embedding capability-based theory within a highly constrained, infrastructure-intensive context. Unlike traditional supply chains, railway systems require coordinated decision-making across tightly coupled operations where disruptions propagate rapidly. The study shows that performance emerges not from isolated capabilities but from a layered capability architecture, in which leadership enables digital capability, digital capability supports agility and agility drives performance. This layered perspective offers a more precise and context-sensitive explanation of performance in complex operational systems.

This study also differs conceptually from prior railway supply chain research that emphasized resilience as the primary operational outcome of leadership and innovation capabilities (Karami, 2026). While resilience primarily reflects the ability to recover and restore operational continuity after disruptions, supply chain agility focuses more directly on rapid responsiveness, coordination speed and adaptive execution during ongoing operational disturbances. In addition, prior studies have largely examined innovation as a broad organizational capability associated with long-term adaptation and competitive positioning, whereas the present study specifically examines digital capability as an operationally embedded resource that enables real-time coordination, visibility and synchronized decision-making across railway networks. Accordingly, this study shifts the emphasis from post-disruption recovery toward real-time operational responsiveness, thereby providing a more execution-oriented explanation of how performance is generated within tightly constrained railway systems.

### 5.3 Interpretation of relationships

The results indicate that leadership has a strong effect on digital capability and a moderate but significant direct effect on supply chain agility, suggesting that leadership operates through both capability-building and operational pathways. The stronger effect on digital capability reflects the role of leadership in shaping strategic direction, allocating resources and supporting the integration of digital systems, which are prerequisites for capability development. In contrast, the relatively weaker direct effect on agility suggests that operational responsiveness is more strongly driven by embedded processes and technological enablement than by managerial intervention alone. This distinction is particularly relevant in railway systems, where operational routines are highly standardized and constrained by infrastructure, limiting the extent to which leadership can directly influence real-time responsiveness.

These findings highlight that while leadership is essential for enabling transformation, its impact on performance is largely indirect and contingent on the development of digital capability and the activation of agile processes. This reinforces the argument that managerial influence must be translated into structured capabilities to generate measurable operational outcomes, particularly in complex and interdependent supply chain environments. Importantly, leadership in this context operates as a coordination-enabling capability rather than a discretionary or style-based influence, reflecting the sequential, tightly coupled and constraint-driven nature of railway operations.

Digital capability indicates both direct and indirect effects on operational performance, with the indirect effect occurring through supply chain agility. Notably, the relationship between digital capability and supply chain agility is substantially stronger than the direct relationship between digital capability and operational performance. This finding provides empirical support for the widely discussed “productivity paradox” associated with digital

transformation in infrastructure-intensive sectors, where investments in advanced technologies do not automatically generate proportional operational improvements.

In railway systems, digital technologies such as predictive analytics, real-time monitoring platforms and integrated scheduling systems primarily enhance visibility, coordination and information synchronization rather than directly improving operational outcomes on their own. Operational value emerges when these digital insights are translated into coordinated and responsive actions across interconnected railway activities. Consequently, supply chain agility functions as a critical execution mechanism that converts digital capability into effective operational performance through adaptive scheduling, disruption response and synchronized decision-making. The findings indicate that digital transformation should not be viewed as a purely technological initiative or an isolated source of performance advantage. Rather, its effectiveness depends on how successfully organizations operationalize digital capability through agile processes, coordination structures and responsive execution mechanisms within tightly constrained operational environments.

#### *5.4 Practical implications*

The findings provide several important implications for managers in railway and logistics organizations. First, leadership should actively drive digital transformation by aligning strategic priorities with investments in digital technologies such as predictive analytics, real-time monitoring, integrated scheduling systems and network-wide coordination platforms. Given the complexity of railway operations, leadership must ensure coordination across scheduling, maintenance, signaling and operational control units to maximize the benefits of digital capability. These findings are particularly relevant within the current railway industry context, where large-scale digital transformation initiatives such as RailPulse and AI-driven railway analytics platforms increasingly emphasize real-time asset visibility, predictive maintenance and intelligent operational coordination. However, the findings of this study suggest that technological investments alone may not consistently generate substantial operational improvements unless they are effectively integrated into agile coordination structures and responsive operational processes throughout the railway network.

Second, organizations should focus on developing supply chain agility alongside digital capability. Investments in digital technologies must be complemented by process redesign, workforce training and improved coordination mechanisms to ensure that digital insights are effectively translated into rapid operational responses and synchronized execution across railway networks. The direct effect of leadership on agility suggests that managerial practices, communication structures and decision-making processes play a crucial role in enhancing responsiveness. By integrating leadership, digital capability and agile operational practices, railway organizations can improve service reliability, reduce network delays and achieve sustained operational performance improvements.

#### *5.5 Robustness and generalizability*

The robustness checks indicate that the observed relationships are stable and not significantly influenced by firm size or respondent role. This suggests that the findings are not driven by specific organizational characteristics and can be generalized across different types of railway organizations. In addition, multi-group analysis indicates that the relationships remain consistent across Canada, the United States and Mexico, despite differences in infrastructure scale and regulatory environments.

These findings suggest that the proposed model captures underlying mechanisms that are applicable across North American railway systems. However, while the results support generalizability within this regional context, caution should be exercised when extending the findings to other industries or regions with different institutional structures, technological maturity levels or operational complexities that may influence the relationships among leadership, capability and performance.

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### 5.6 Limitations and future research

This study has several limitations that provide opportunities for future research. First, the cross-sectional design limits the ability to capture the dynamic evolution of digital capability and supply chain agility over time. Future research could adopt longitudinal designs to better understand how these capabilities develop and interact in response to technological and environmental changes.

Second, the study relies on perceptual measures of operational performance, which, although widely used in supply chain research, may not fully capture objective performance outcomes such as delay minutes, on-time performance rates or asset utilization metrics. Future studies should incorporate objective railway performance indicators to enhance measurement precision and validate the observed relationships.

Third, the data were collected using a single-source, single-informant survey approach, which may still introduce potential common method variance despite the procedural and statistical remedies applied. Although multiple procedural and statistical assessments suggest that common method bias is unlikely to substantially affect the findings, future research could employ multi-informant designs or combine survey data with archival operational data to further strengthen validity.

Fourth, while the inclusion of multiple railway-related organizational roles reflects the integrated and interdependent structure of railway supply chains, differences in operational responsibilities may still introduce unobserved heterogeneity. Future studies could examine railway operators, infrastructure organizations and logistics coordination firms separately to explore potential differences in capability deployment and operational performance mechanisms.

Finally, the study focuses on railway supply chains within North America, which may limit the generalizability of the findings to regions with different regulatory environments, infrastructure characteristics or levels of digital maturity. Future research could extend this model to other geographical contexts or compare developed and emerging railway systems to assess the boundary conditions of the proposed relationships.

## 6. Conclusion

This study addresses an important gap in understanding how leadership influences supply chain agility both directly and indirectly through digital capability within railway supply chains in North America. Drawing on the Resource-Based View and Dynamic Capabilities perspective, the findings demonstrate that leadership plays a dual role by enabling digital capability and directly enhancing agility. Digital capability, in turn, improves operational performance both directly and indirectly through supply chain agility. These results clarify that performance in infrastructure-intensive environments is shaped by an integrated system of leadership, technological capability and adaptive operational processes rather than isolated factors.

This study contributes in three keyways. First, it extends the Resource-Based View by demonstrating that digital capability functions as a strategic resource that directly and indirectly influences performance outcomes in railway supply chains. Second, it advances Dynamic Capabilities theory by identifying supply chain agility as a mechanism through which digital capability is translated into operational performance. Third, it highlights the dual role of leadership as both a driver of capability development and a direct enabler of agility, thereby offering a more comprehensive understanding of performance drivers in complex systems.

From a practical perspective, the findings suggest that organizations should not treat digital transformation as a purely technological initiative. Instead, leadership must align digital investments with operational processes, coordination mechanisms and organizational practices that enhance responsiveness, synchronization and real-time operational execution across railway networks. In railway systems, this involves integrating digital tools with

scheduling, maintenance and operational decision-making processes to improve reliability and efficiency. More broadly, the study emphasizes that the value of digital capability depends on how effectively digital resources are operationalized through agile coordination structures and execution-oriented operational processes.

In conclusion, achieving sustainable operational performance within railway supply chains requires an integrated and carefully coordinated approach in which leadership enables digital capability and digital capability is translated into supply chain agility and operational effectiveness. Railway organizations that effectively align leadership coordination, digital capability and agile operational processes may be better positioned to manage operational complexity, respond to network uncertainty and sustain long-term operational performance under infrastructure-constrained conditions. Overall, the findings suggest that digital transformation is more likely to create operational value when technological initiatives are strategically coordinated, operationally enacted and continuously adapted within railway systems.

### Supplementary material

The supplementary material for this article can be found online

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