International Journal of Railway Research, Vol. 13, No. 1, (2026), 71-87

Iran University of Science and Technology

International Journal of

Railway Research

ISSN: 2361-5376

Improving Supply Chain Performance Using SCQM model; A Case study of Tehran Wagon Manufacturing Company

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ARTICLE INFO

Article history:

Received: 11.03.2026

Accepted:20.06.2026

Published:27.06.2026

Keywords:

Supply Chain Quality Management,

Performance Evaluation,

Performance Improvement,

Wagon Manufacturing Industry.

A B S T R A C T

Continuous improvement in supply chain performance requires the development of a reliable and structured performance evaluation system. This study employs the Supply Chain Quality Management (SCQM) model to assess and improve the supply chain performance of Tehran Wagon Manufacturing Company. Based on a comprehensive literature review and expert input, ten key performance criteria were identified, including supplier quality management, systemic integration, customer and market focus, stakeholder communication, management commitment, quality information systems, leadership, process management, quality strategies, and human resource development.

Sub-criteria were defined for each main criterion, and their weights were determined using the Analytic Hierarchy Process (AHP). Performance was then measured using the Zero-Level and Target-Level method, resulting in an overall performance score of 48%. Regression and dynamic analyses revealed both direct and indirect relationships among the criteria, emphasizing the presence of synergistic effects—where improvements in one area positively influence others. The SCQM model proves to be an effective tool for structured supply chain performance optimization. Future research is recommended to enhance the model through advanced analytical methods and cross-industry comparisons.

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1. Introduction

Supply chain performance refers to the efficiency and effectiveness with which supply chain activities such as procurement, production, distribution, and logistics are coordinated to meet customer demands and organizational goals [1,2].

High-performing supply chains respond quickly to market changes, minimize waste, and maintain strong relationships with suppliers and customers, thereby creating competitive advantage [3,4]. Improving supply chain performance has therefore become a strategic priority for organizations seeking to enhance competitiveness, reduce operational costs, and increase customer satisfaction through data-driven decision making, technological adoption, and stronger collaboration among supply chain partners [5,6,7,8]. These improvements can lead to greater operational efficiency, reduced delays and inventory costs, improved product and service quality, and better coordination among supply chain actors [9,10,11,12,13].

Despite these advantages, improving supply chain performance remains challenging due to issues such as stakeholder coordination, technology integration, investment requirements, and data transparency [14,15,16]. In addition, external factors such as market volatility and global disruptions can significantly affect supply chain stability, highlighting the need for effective management and continuous improvement [17].

Various models have been proposed to enhance supply chain performance across different industries [18]. Among them, the Supply Chain Quality Management (SCQM) model has gained increasing attention because it integrates quality management principles with supply chain operations and emphasizes continuous improvement, supplier quality assurance, and collaboration among partners to enhance quality, reliability, and overall supply chain responsiveness [19,20,21,22]

In today's competitive industrial environment, organizations face increasing pressure to improve the efficiency and coordination of their supply chains. However, many companies still lack comprehensive and reliable performance evaluation systems that allow them to identify inefficiencies and improve coordination among supply chain partners. This challenge is particularly significant in complex industries such as railway manufacturing, where multiple suppliers, strict quality requirements, and highly interdependent processes must operate in a coordinated manner to ensure product reliability.

This study aims to assess and improve the supply chain performance of Tehran Wagon Manufacturing Company by applying the Supply Chain Quality Management (SCQM) model. The study identifies key performance criteria and analyzes their interdependencies in order to provide practical strategies for supply chain performance improvement.

Although numerous studies have investigated general supply chain performance models, relatively limited attention has been paid to the application of SCQM in the railway manufacturing sector. In addition, most previous studies evaluate performance criteria independently and do not analyze the dynamic relationships among them within real industrial contexts. As a result, managers often lack a clear understanding of how different supply chain performance factors interact and influence overall performance. To address this gap, this research combines expert insights with a quantitative evaluation framework to analyze the interdependencies among SCQM performance criteria in Tehran Wagon Manufacturing Company.

This paper is structured into five main sections to ensure a logical and comprehensive presentation of the research. The Introduction outlines the background, research problem, and objectives of the study. The Literature Review explores previous studies related to supply chain quality management and identifies key performance criteria. The Research Method section describes the methodology used, including the application of the SCQM model, data collection, and analytical techniques such as AHP and regression analysis. The Discussion interprets the results, highlights the direct and indirect relationships among criteria, and presents strategic insights. Finally, the Conclusion summarizes the key findings, emphasizes the

practical implications, and offers recommendations for future research.

2. Literature Review

Supply Chain Quality Management (SCQM) has emerged as an important concept that integrates quality management principles with supply chain management practices. Early studies emphasized the need to shift from firm-level quality initiatives toward inter-organizational collaboration across the supply chain. For example, a 2005 study introduced the concept of SCQM and highlighted the fragmented integration between quality management and supply chain practices, calling for a process-oriented and collaborative approach to improve overall supply chain performance [23]. Similarly, another study demonstrated that integrating quality management with supply chain practices enhances organizational performance by promoting collaboration rather than merely focusing on cost reduction, enabling firms to develop more flexible and responsive supply chains [24]. In line with this perspective, later research showed that applying Total Quality Management (TQM) principles across supply chain partners improves operational efficiency and strengthens competitive advantage through coordinated quality efforts and closer supplier relationships [25].

Subsequent studies expanded the SCQM perspective by developing conceptual frameworks and examining its operational drivers. A strategic SCQM framework was proposed to identify key drivers of supply chain quality and to analyze stakeholder perceptions using the Analytic Hierarchy Process (AHP), revealing significant perception gaps among supply chain actors and emphasizing the importance of coordinated quality initiatives [26]. In addition, the concept of sustainable supply chain quality management (SSCQM) has been introduced as an extension of SCQM, linking quality management standards such as ISO 9001 with supply chain integration and the triple bottom line approach to sustainability [27].

Another stream of research has focused on performance measurement and evaluation methods for supply chains. Several studies have developed analytical approaches to identify and prioritize key supply chain performance indicators. For instance, a grey-based rough set method was proposed to simplify ecological and business performance metrics in supply chains, enabling organizations to focus on critical indicators and reduce complexity in sustainability evaluation [28]. In the food supply chain context, a balanced scorecard framework was developed and validated through expert opinions and case studies, identifying key performance indicators across multiple perspectives [29].

Furthermore, multi-criteria decision-making techniques have been widely used to evaluate and improve supply chain processes. Integrating the SCOR model with AHP has been shown to support organizations in identifying and prioritizing critical supply chain processes for redesign and strategic improvement [30]. Similarly, another study combined SCOR, AHP, and TOPSIS methods to benchmark supply chain performance and align strategic objectives with operational performance metrics [31]. In addition, empirical research in the hospitality industry demonstrated that supply chain quality plays a mediating role between quality management practices and organizational performance, highlighting the influence of external environmental factors such as market dynamics on these relationships [32]

Despite the growing body of research on supply chain quality management and supply chain performance evaluation, several limitations remain in the existing literature. First, many studies primarily focus on conceptual frameworks or general manufacturing contexts, with limited attention to industry-specific supply chains where operational complexities and stakeholder interactions may differ significantly. Second, although various performance evaluation models and multi-criteria decision-making methods such as AHP, SCOR, and TOPSIS have been applied to assess supply chain performance, most studies evaluate performance indicators independently and pay limited attention to the dynamic interrelationships among these criteria. Third, while the integration of quality management principles with supply chain management has been widely acknowledged, empirical studies examining SCQM within real organizational settings—particularly in

specialized manufacturing sectors—remain relatively scarce.

Therefore, there is still a need for studies that simultaneously integrate SCQM principles with systematic performance evaluation approaches while considering the interactions among supply chain performance criteria in a real industrial context. To address this gap, the present study develops an analytical framework for evaluating supply chain performance based on SCQM principles and applies it to the railway manufacturing industry. By combining multi-criteria evaluation techniques with empirical data from a real organizational environment, this study aims to provide a more comprehensive understanding of the relationships among supply chain quality factors and their impact on overall supply chain performance.

To provide a clearer overview of the existing literature and highlight the position of the present study, the main characteristics of the reviewed studies are summarized in Table 1. The table compares the previous studies in terms of research approach, context, and main contributions, and it also illustrates how the current research differs from and extends prior work in the field of supply chain quality management and supply chain performance evaluation.

Table 1- Comparative Summary of Reviewed Studies

Ref	Year	Method / Approach	Context	Main Contribution	Mostly conceptual, limited empirical validation
[23]	2005	Conceptual framework	Supply chain quality management	Introduced the concept of SCQM and emphasized integration of quality management with supply chain practices	Mostly conceptual, limited empirical validation
[24]	2005	Conceptual / empirical discussion	Supply chain integration	Showed that integrating quality management with supply chain practices improves responsiveness and collaboration	Limited analytical modeling
[25]	2009	TQM-based analysis	Supply chain management	Showed that applying TQM across the supply chain improves efficiency and competitiveness	Limited analysis of performance evaluation methods
[26]	2008	AHP	SCQM strategic framework	Identified key drivers of SCQM and analyzed stakeholder perception gaps	Focus mainly on strategic drivers
[27]	2025	SCQM + Multi-criteria evaluation	Railway manufacturing industry	Evaluates supply chain performance based on SCQM principles and analyzes relationships among performance criteria	-
[28]	2012	Grey-based rough set method	Sustainable supply chains	Reduced complexity of ecological and business performance indicators	Focused mainly on sustainability indicators
[29]	2010	Balanced Scorecard	Food supply chain	Developed and validated supply chain performance indicators	Limited analysis of interrelationships among indicators
[30]	2014	SCOR + AHP	Supply chain process evaluation	Prioritized key supply chain processes for redesign and strategic improvement	Focus on process prioritization
[31]	2013	SCOR + AHP + TOPSIS	Supply chain benchmarking	Provided structured benchmarking and ranking of supply chain performance scenarios	Limited focus on quality integration
[32]	2016	Empirical analysis	Hotel industry	Demonstrated mediating role of supply chain quality between management practices and performance	Industry-specific context

3. Research Method

This paper adopts a structured methodological approach to identify, validate, and prioritize supply chain quality management (SCQM) performance indicators in the railway manufacturing industry. The research process consists of several sequential stages, beginning with the identification of relevant indicators through a comprehensive literature review, followed by expert validation and analytical evaluation. The overall workflow of the research process is illustrated in Figure 1.

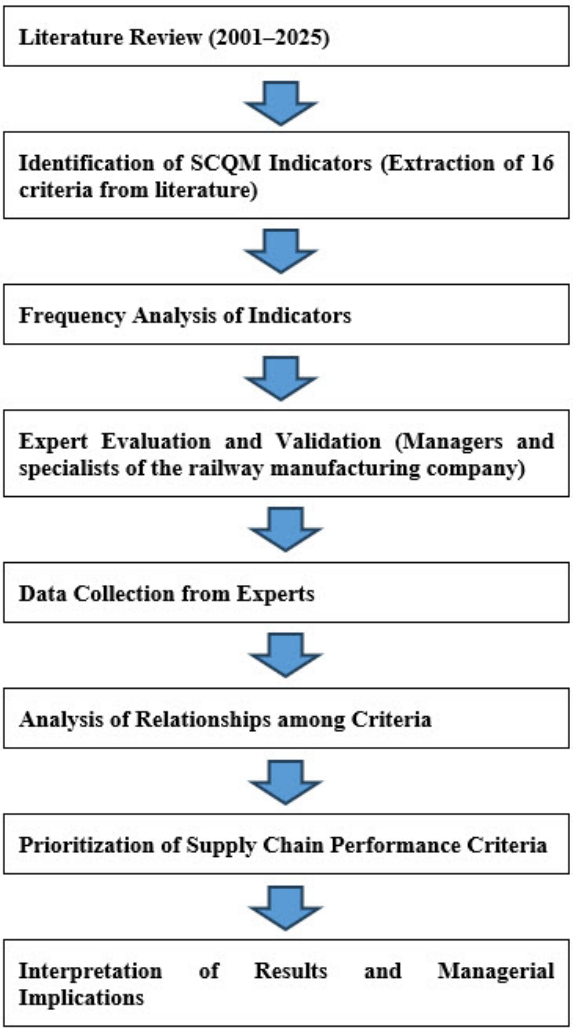

Figure 1. Research methodology framework of the study

Following a literature review covering the period from 2001 to 2024, a total of 16 key criteria were extracted from the examined studies. These criteria represent the most frequently discussed indicators related to supply chain quality management and supply chain performance evaluation in previous research. The identified criteria and their frequency of occurrence in the literature are presented in Table 2. Although the initial set of indicators was derived from the literature, expert evaluation was necessary to ensure their relevance and applicability to the specific context of railway manufacturing. Therefore, industry experts were asked to review the indicators and select those that were most appropriate for evaluating supply chain quality management in the studied company.

Table 2- SCQM Criteria Identified in the Literature

Row	Criteria	Frequency of Occurrence
1	Customer and Market Focus	7
2	Supplier Quality Management	4
3	Supply Chain Quality Leadership	5
4	Supply Chain Quality Strategies	5
5	Process Integration and Management Across the Supply Chain	5
6	Supply Chain Quality Information Systems and Data Analysis	5
7	Human Resource Development and Management in the Supply Chain	5
8	Customer and Supplier Communication	4
9	Management Commitment	2
10	Role of the Quality Department	1
11	In-Service Training	1
12	Quality Data and Reporting	1
13	Best Practices	1

14	Systemic Approach to Supply Chain Management	1
15	Continuous Improvement in Supply Chain Management	1
16	Fact-Based Decision Making in the Supply Chain	1

To ensure the relevance of these indicators to the railway manufacturing context, a questionnaire was developed and distributed among experts in the railway manufacturing industry. The purpose of this stage was to validate and refine the literature-based indicators according to industry practices. Based on the experts' responses, 10 out of the 16 criteria listed in Table 2 were identified as the key performance evaluation indicators for the Tehran Wagon Manufacturing Company. These included: Supplier Quality Management, Systemic Integration in the Supply Chain, Customer and Market Focus, Communication with Customers and Suppliers, Management Commitment, Supply Chain Quality Information Systems, Supply Chain Quality Leadership, Process Management Across the Supply Chain, Supply Chain Quality Strategies, and Human Resource Development in the Supply Chain.

Subsequently, in order to determine the relative importance (weights) of these criteria, a second questionnaire was designed using the Analytic Hierarchy Process (AHP) method. It was distributed among 15 experts and specialists from the Tehran Wagon Manufacturing Company. The resulting weights for each criterion are presented in Table 3.

Table 3- Weight of Each Evaluation Criterion

Row	Criteria	Weight
1	Supplier Quality Management	0.137
2	Systemic Integration in the Supply Chain	0.136
3	Customer and Market Focus	0.121
4	Customer and Supplier Communication	0.114
5	Process Management Across the Supply Chain	0.091
6	Supply Chain Quality Information Systems	0.09
7	Human Resource Development and Management in the Supply Chain	0.085
8	Management Commitment	0.078
9	Supply Chain Quality Strategies	0.076
10	Supply Chain Quality Leadership	0.072

Given that the selected criteria are broad and high-level, it is necessary to define sub-criteria for each of them in order to enable a more precise evaluation of the company's performance in each area. These sub-criteria were identified through a comprehensive review of the literature as well as consultations with industry experts. Subsequently, their relative weights were determined using a pairwise comparison questionnaire completed by the expert panel. The sub-criteria and their corresponding weights are presented in Table 4.

Table 4- Sub-Criteria and Their Respective Weights

Criteria	Sub- Criteria	Weight
Supplier Quality Management	Tolerance Rate for Non-Conformities Issued by the Quality Control Unit	0.18
	Number of Inspected Items Lacking Quality Reports	0.05
	Average Time from Inspection Request Issuance to Initiation of Corrective Actions	0.05
	Number of Suppliers with More Than Two Non-Conformities	0.1
	Number of Non-Conformities Issued by the Production Unit	0.12
	Average Percentage of Contractor Deliveries Compared to Monthly Planned Orders	0.1
	Average Percentage of Contractor Deliveries Compared to Total Cumulative Orders	0.1

	Number of Undecided Non-Conforming Shipments	0.1
	Ratio of Shipments Approved by the Quality Control Unit to Total Ordered Shipments	0.1
	Number of Suppliers Whose Inability Was Not Identified During Evaluation	0.1
Systemic Integration and Approach in the Supply Chain	Stakeholder Engagement in Design and Decision-Making by Senior Management (including customers, suppliers, managers, and employees)	0.17
	Effective Participation and Interaction Among Supply Chain Members	0.15
	Systemic Approach to Problem Solving by Considering the Entire Supply Chain	0.23
	Alignment of Supply Chain Members' Goals with the Organization's Objectives	0.27
	Lack of Conflict Among Activities of Supply Chain Members	0.18
Customer and Market Focus	Average Level of Customer Satisfaction	0.6
	Average Delay in Measuring Customer Satisfaction	0.1
	Market Share	0.3
Communication with Customers and Suppliers	Bid Success Rate	0.1
	Effectiveness of Marketing Activities	0.19
	Number of Issues Arising in Internal Contracts	0.08
	Average Total Delay in Order Delivery	0.07
	Percentage of Orders That Encountered Execution Problems	0.1
	Average Production Downtime Due to Late Delivery of Items by Contractors	0.16
	Delay in Delivering Products to Customers	0.3
Management Commitment	Managerial Accountability Across All Organizational Domains	0.27
	Managers' In-Depth Understanding of the Organization's Supply Chain Issues	0.2
	Managers' Collection of Feedback from Informal Employee Leaders	0.14
	Compliance with Quantitative and Qualitative Standards in Achieving Organizational Goals	0.2
	Creating Employee Satisfaction and Work Commitment by Management	0.19
Supply Chain Quality Information Systems	Efficiency in Collecting, Classifying, Storing, and Retrieving Quality-Related Information Across the Supply Chain	0.14
	Efficiency of Data Transmission Processes Within the Supply Chain	0.13
	Access to Essential Information for Evaluating Quality Indicators	0.13
	Analysis of Quality Indicators for Generating Quality Performance Reports	0.13
	Ability to Monitor Organizational Unit Performance and Implement Corrective Actions Through the Quality Information System	0.12
	Availability of Required Information for Decision-Making at All Organizational Levels	0.13
	Accuracy, Timeliness, and Reliability of Available Information	0.15
	Alignment of the Existing Quality Information System with Management's Information Needs	0.07
Supply Chain Quality Leadership	Managers' Emphasis on Defining and Upholding the Supply Chain's Mission, Vision, Quality Values, and Ethical Principles	0.21

and Management	Monitoring, Reviewing, and Guiding Organizational Performance and Management System Improvements	0.29
	Managers' Engagement with Customers, Suppliers, Partners, and Community Representatives	0.18
	Promoting a Culture of Quality Excellence Among Employees	0.16
	Organizational Flexibility and Effective Change Management by Leadership	0.16
Process Management	Effectiveness of Quality Management Standard Implementation	0.19
	Percentage of Units with Declining Performance in Audits	0.21
	Ratio of Unfollowed Corrective Actions to Total Corrective Actions	0.11
	Percentage of Non-Conformities Addressed Within the Quality Control Department	0.05
	Percentage of Resolved Non-Conformities in Quality Control	0.05
	Number of Preventive Actions That Led to Corrective Actions Due to Poor Control	0.1
	Number of Implemented Preventive Actions	0.1
	Percentage of Improvements Achieved Across Organizational Units	0.19
Supply Chain Quality Strategies	Percentage of Items Requiring Rework	0.08
	Percentage of Waste Generated During Production	0.17
	Percentage of Approved and Defect-Free Items in Final Quality Inspections	0.36
	Percentage of Quality Objectives Not Effectively Achieved	0.29
	Percentage of Deviations from the Scheduled Implementation of Quality Objectives	0.1
Human Resource Development and Management in the Supply Chain	Labor Productivity	0.3
	Employee Job Satisfaction Rate	0.17
	Percentage of Suggestions Submitted Relative to Total Employees	0.05
	Percentage of Payments Made Through the Suggestion System Relative to Total Employee Payments	0.05
	Training Effectiveness Rate	0.08
	Percentage of Training Costs Relative to Total Human Resource Expenses	0.08
	Percentage of Units That Refused to Provide Requested Information	0.1
	Percentage of Employees with Insufficient Cooperation in Data and Indicator Collection	0.1
	Degree of Deviation from Planned Activities	0.07

The data required to calculate the sub-criteria were collected from Tehran Wagon Manufacturing Company. Subsequently, the performance percentage for each main criterion was determined using the Zero-Level and Target-Level method. According to this approach, the current value of each sub-criterion is compared with both the desired (target) value and the minimum acceptable level. These benchmark values were defined with the support of the company's experts and specialists. The foundation of this method lies in goal setting; therefore, setting goals that are either too lenient or unattainably ambitious would undermine the effectiveness of the performance evaluation process.

There are two important considerations regarding the goal-setting process for the criteria.

1. If quantitative goals are set at excessively high levels, resources that could have been more effectively allocated to other objectives may be unnecessarily consumed. Conversely, if a large

portion of resources is directed toward minor improvements, the outcomes may prove inefficient and unproductive.

2. Quantitative goals should be able to reveal shortcomings and performance weaknesses so that managers can make informed decisions about whether to allocate additional resources or accept the risks associated with suboptimal performance. In either case, it is crucial to identify the root causes of underperformance and implement corrective actions accordingly. In this method, for criteria that are inherently positive—meaning that an increase in their value is desirable and the target level exceeds the zero level—performance is calculated according to Formula (1).

$$\begin{aligned} n &= 0\% && if\ A < Z \\ n &= 100\% && if\ A > E \\ n &= \frac{A-Z}{E-Z} && if\ Z \leq A \leq E \end{aligned} \quad (1)$$

In this formula, *n* represents the performance of the criterion, *A* is the actual score of the given criterion, *Z* denotes the zero level, and *E* refers to the expected (target) level. For criteria that are inherently negative—meaning that a decrease in their value is desirable and the expected level is lower than the zero level—performance is calculated using Formula (2).

$$\begin{aligned} n &= 0\% && if\ A > Z \\ n &= 100\% && if\ A < E \\ n &= \frac{Z-A}{Z-E} && if\ E \leq A \leq Z \end{aligned} \quad (2)$$

As an example, the performance of the sub-criterion "Number of Non-Conformities Issued by the Production Unit" under the criterion of Supplier Quality Management can be calculated using the Zero-Level and Target-Level method.

Based on expert opinions from the company, the zero level and the expected level for this sub-criterion were determined to be 5 and 0, respectively. The current number of non-conformities issued by production is 1. Since this sub-criterion is inherently negative, its performance is calculated using Formula (2).

$$n = \frac{Z-A}{Z-E} = \frac{5-1}{5-0} = 80\% \quad (3)$$

After calculating the performance percentage for each sub-criterion, the overall performance score for each main criterion is obtained by summing the products of these values and their respective weights. This calculation is illustrated in Formula (3).

$$P_j = \sum n_i * w_i \quad (4)$$

In this formula, P_j represents the performance percentage of criterion *j*, n_i denotes the performance percentage of sub-criterion *i*, and w_i is the weight of sub-criterion *i*. Similarly, after calculating the performance score for each main criterion, the overall supply chain performance is obtained by summing the weighted performance scores of all criteria. For the company under study, the total supply chain performance was calculated to be 48%. This indicates a 52% deviation from the target performance level, while the company's performance exceeds the minimum (zero level) by 48%.

3.1. Proposed Improvement Strategies

In order to propose strategies for improving supply chain performance and to evaluate the potential impact of these strategies, it is necessary to analyze the relationships among the evaluation criteria and examine how they influence overall supply chain performance. To investigate these interrelationships, a dynamic analysis approach was employed. In this approach, initial hypotheses regarding the relationships among criteria were formulated based on insights from the literature and expert opinions. These hypotheses were subsequently examined using statistical analysis in order to confirm or reject the assumed relationships. Once the relationships among the criteria were established, it became possible to estimate how changes in one criterion may influence the others.

3.1.1. Dynamic Analysis of the Criteria

Since the ten main criteria identified in this study are positively oriented, an improvement in the performance of any individual criterion contributes to an increase in overall supply chain performance. However, improvements in one criterion may also influence other criteria, which makes it necessary to examine the interdependencies among them.

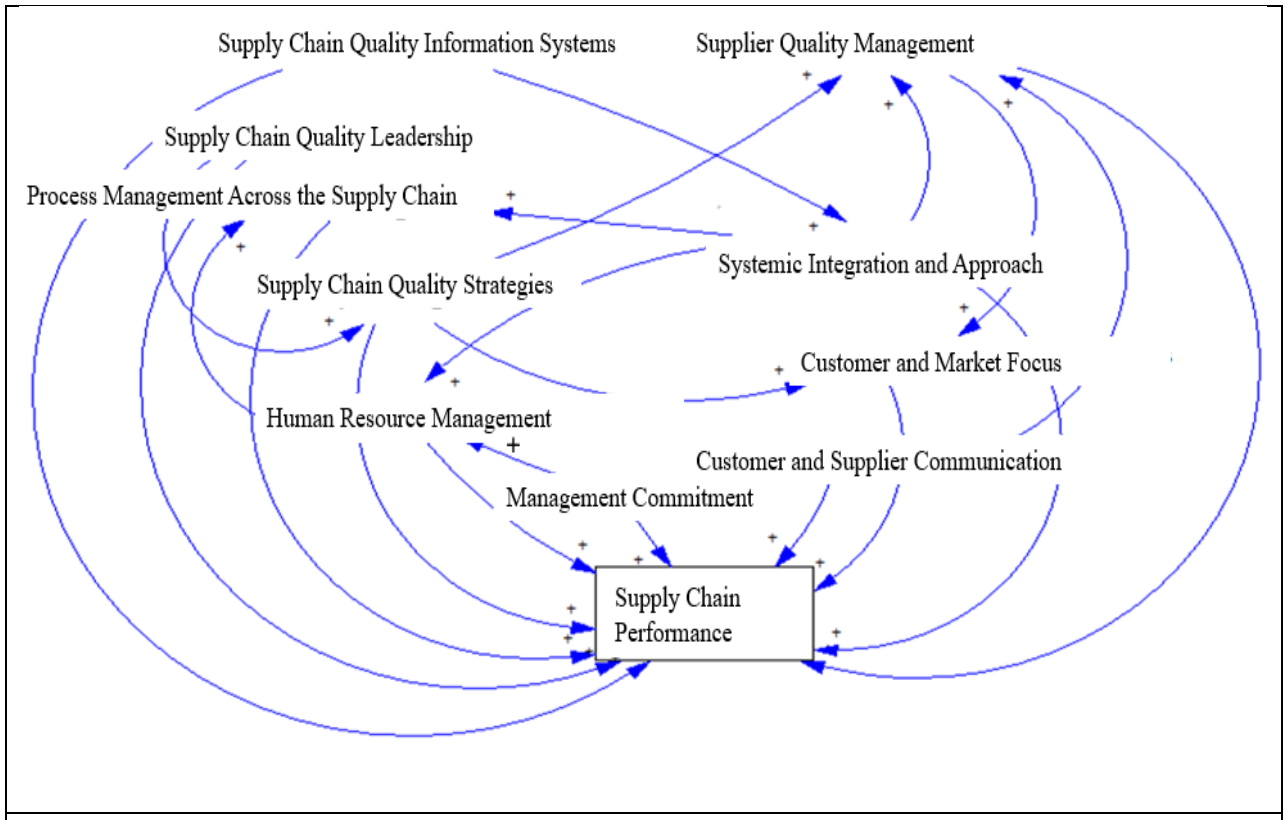

Figure 2: Causal Relationships Among the Criteria and Overall Performance

To identify these dependencies, a questionnaire was developed to evaluate the possible relationships among the ten primary criteria. The questionnaire sought to determine which criteria influence others and how changes in one criterion may affect the remaining criteria. After collecting responses from experts and specialists at Tehran Wagon Manufacturing Company, hypotheses regarding the relationships among the criteria were formulated. The resulting cause-and-effect relationships among the criteria are illustrated in Figure 2.

Based on Figure 2, the causal relationships among the ten main criteria of supply chain quality management and their overall impact on supply chain performance are clearly illustrated. Each arrow marked with a plus sign (+) indicates a direct and positive influence—implying that improvement in one criterion contributes to the enhancement of another. For instance, enhancements in "Quality Information Systems" strengthen both "Systemic Integration" and "Quality Leadership," which subsequently affect other related criteria. Likewise, "Management Commitment" indirectly supports performance by influencing "Customer and Supplier Communication" and "Human Resource Development."

This interconnected framework highlights that improving a single criterion can trigger both direct and indirect improvements across the supply chain through a network of reinforcing relationships. The existence of multiple positive feedback loops suggests synergy among the criteria, where changes in one area can amplify changes in others. Therefore, a dynamic and system-wide perspective is essential for identifying leverage points and prioritizing actions for improvement. Decision-makers should avoid viewing criteria in isolation and instead consider their collective and cascading effects on overall performance.

3.1.2. Validation of the Causal Relationships

To validate the causal relationships proposed in the dynamic analysis, historical performance data for each criterion were collected for the first and second half of each year from 2010 to 2024 (1389–1403 in the Persian calendar). These data were used to examine whether the hypothesized relationships among the criteria were statistically supported. The collected performance values were entered into SPSS software, and regression analysis was conducted to test the significance of the relationships between the criteria. Each hypothesized causal relationship was evaluated by examining the statistical significance of the regression coefficients. The results indicated that some of the relationships initially proposed in the causal diagram were not statistically significant. Therefore, these relationships were removed from the model. The refined causal diagram, which includes only the statistically validated relationships, is presented in Figure 3.

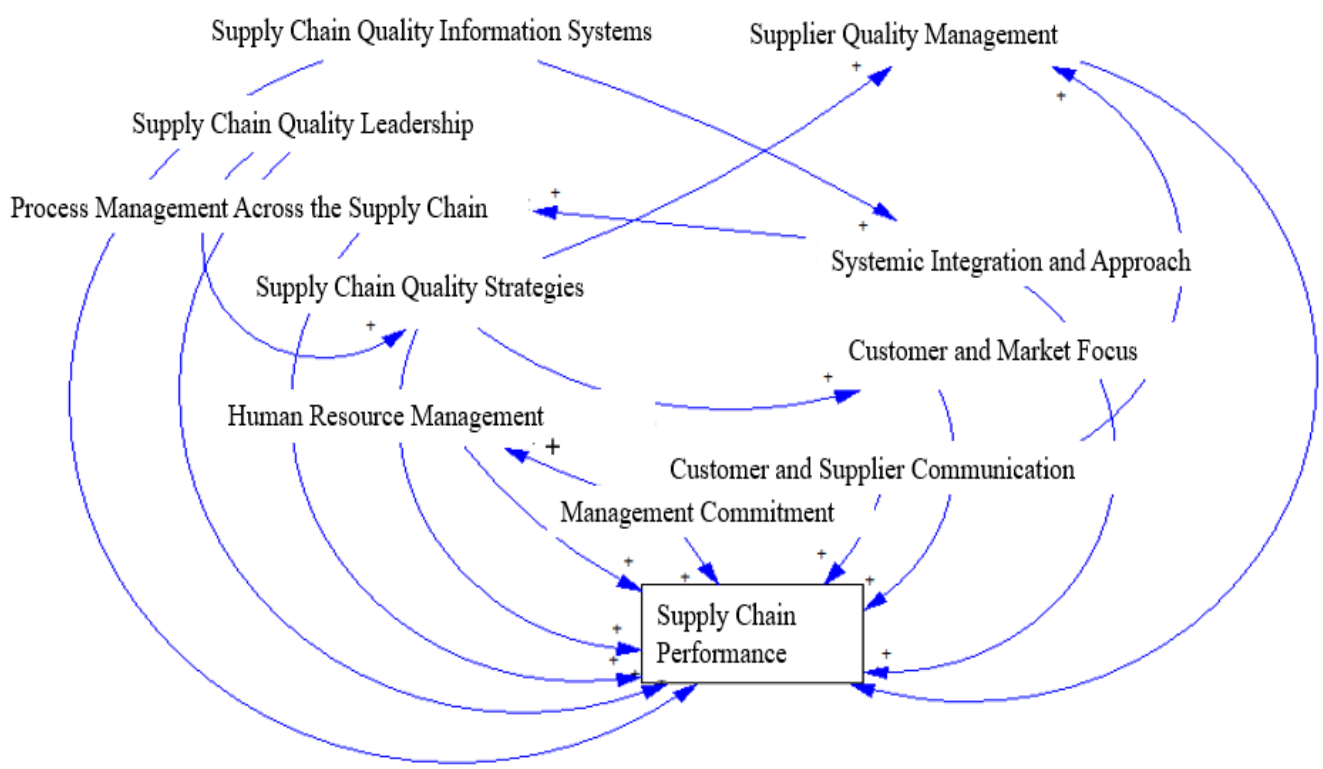

Figure 3: Revised Causal Relationships and Overall Performance

The refined diagram highlights direct influences of certain criteria—such as "Supplier Quality Management," "Customer and Supplier Communication," and "Human Resource Management"—on overall supply chain performance. It also confirms that "Systemic Integration" and "Quality Information Systems" play a mediating role by affecting other key areas like "Process Management" and "Leadership." By narrowing the relationships to only those supported by empirical evidence, this model allows for more precise targeting of improvement initiatives, ensuring that organizational efforts are focused where they will have the greatest impact.

3.1.3. Sensitivity Analysis and Interrelationships Among Variables

Regarding the impact of each criterion's performance on the overall supply chain performance and its sensitivity analysis, it can be stated that a 1% change in the performance of a specific criterion will lead to a change in the overall performance equal to ($\frac{Criterion\ weight}{100}$). For example, for the "Supplier Quality Management" criterion, a 1% increase in performance would result in a 0.137% increase in the overall supply chain performance.

Following the performance analysis across multiple years and the application of dynamic analysis and regression techniques, it was found that in addition to each criterion having a direct impact on the overall supply chain performance, some criteria also have reinforcing relationships with one another. As a result, the influence of each criterion on the others was calculated. These interrelationships are presented in the table below using two statistical variables: **B**, the unstandardized regression coefficient, and **sig**, the significance level. According to the table, a 1% increase in the performance of an independent criterion is expected to result in a **B%** increase in the dependent criterion's performance, with a probability of **(1 − sig)**.

For example, the table shows that a 1% increase in the performance of the "Supply Chain Quality Strategies" criterion would, with 95% confidence, lead to a 1.149% increase in "Customer and Market Focus." Similarly, with 97% confidence, it would result in a 0.273% increase in "Supplier Quality Management." The influence of each criterion on others (where applicable) is detailed in Table 4.

Table 4- The extent of the impact of each indicator on each other

Dependent Criteria	Independent Criteria	B	Sig
Supplier Quality Management	Customer and Supplier Communication	0.382	0.002
	Supply Chain Quality Strategies	0.273	0.025
Systemic Integration and Approach in the Supply Chain	Supply Chain Quality Information Systems	0.0924	0.0001
Customer and Market Focus	Supply Chain Quality Strategies	1.149	0.048
Process Management Across the Supply Chain	Systemic Integration and Approach in the Supply Chain	0.711	0.0001
Supply Chain Quality Strategies	Supply Chain Quality Leadership	0.891	0.0001
Human Resource Development and Management in the Supply Chain	Management Commitment	0.912	0.0001

Therefore, an increase in the performance percentage of each criterion not only has a direct impact on the overall supply chain performance, but may also lead to indirect improvements by influencing other criteria. Consequently, when a criterion's performance increases, both its direct and indirect effects on overall supply chain performance must be calculated and considered as a whole. For this purpose, Formula (4) has been used to determine the total impact of an improvement in a single criterion on overall supply chain performance.

$$E_i = X_i\left(W_i + \sum_{j=1}^{k} B_{ij} * W_j\right) * 100 \qquad (4)$$

In this formula, E_i represents the percentage impact of improving criterion *i* on overall supply chain performance, X_i is the amount of

performance improvement in criterion *i*, B_{ij} is the unstandardized regression coefficient (i.e., the effect of independent criterion *i* on dependent criterion *j*), and *k* denotes the number of criteria influenced by criterion *i*.

For example, if an improvement initiative is implemented that results in a 16% increase in the performance of the "Customer and Supplier Communication" criterion, it will lead to an estimated 2.66% increase in overall supply chain performance.

4. Discussion

In This study aimed to enhance the performance of the supply chain in the wagon manufacturing industry by applying the Supply Chain Quality Management (SCQM) model to the Tehran Wagon Manufacturing Company. The research began with a comprehensive literature review, from which 16 criteria were extracted based on their frequency and relevance. Using expert input, this list was refined to 10 high-priority criteria. These were then further analyzed by identifying related sub-criteria, each weighted through pairwise comparison using the Analytic Hierarchy Process (AHP).

The performance of each criterion was assessed using the Zero-Level and Target-Level method, where actual performance values were compared against expert-defined benchmarks. Based on the analysis, the overall supply chain performance was calculated to be 48%, indicating a significant 52% deviation from the expected target level, while still outperforming the minimum baseline. Furthermore, causal relationships among the criteria were examined through dynamic modeling and regression analysis using SPSS. This process led to a revised causal map that retained only statistically significant relationships, offering a clearer view of how individual improvements propagate across the supply chain system.

Sensitivity analysis revealed that improving the performance of any given criterion has a measurable direct impact on the overall supply chain performance, proportional to its assigned weight. For instance, a 1% increase in "Supplier Quality Management" resulted in a 0.137% rise in overall performance. Moreover, indirect impacts were identified via inter-criterion relationships. For example, a 1% improvement in "Supply Chain Quality Strategies" led to a 1.149% increase in "Customer and Market Focus," and a 0.273% increase in "Supplier Quality Management." Such findings confirm that improvements in certain key areas can yield amplified effects throughout the supply chain.

In light of these results, several strategic insights emerge. First, organizations should prioritize improvement initiatives in criteria that both directly affect overall performance and exert influence on other criteria. Second, the use of dynamic analysis enables decision-makers to identify leverage points for maximum impact. Finally, integrating SCQM into routine performance evaluations can foster continuous improvement, resilience, and long-term competitiveness.

Recent studies have also shown that the integration of advanced technologies such as RFID and AI , sustainable supply chains and AI can significantly enhance warehouse efficiency, inventory accuracy, and cost reduction, as demonstrated by major competitors in the retail industry [33, 34].

Additionally, recent studies in urban transport development have highlighted the effectiveness of Multi-Criteria Decision-Making (MCDM) models, such as the Analytic Hierarchy Process (AHP), in prioritizing and optimizing infrastructure projects. These decision-making techniques, commonly used in metro system planning, can similarly be applied to supply chain management to enhance resource allocation and improve operational efficiency [35].

Future research can expand upon this model by incorporating real-time performance data, exploring cross-industry comparisons, or integrating advanced machine learning techniques to refine predictive accuracy. Additionally, exploring the impact of external disruptions—such as geopolitical shifts or supply shocks—within this framework could offer valuable strategic foresight for supply chain resilience planning.

5. Conclusion

This study investigated the application of a Supply Chain Quality Management (SCQM) framework to evaluate and improve the supply chain performance of Tehran Wagon

Manufacturing Company. Based on an extensive literature review, sixteen SCQM criteria were initially identified, from which ten key criteria were selected through expert evaluation to reflect the specific characteristics of the railway manufacturing industry.

The results of the performance assessment using the Zero-Level and Target-Level method indicated that the overall supply chain performance of the company is approximately 48%, revealing a considerable gap between the current condition and the desired performance level. This evaluation enabled the identification of the most influential criteria affecting supply chain performance and highlighted areas that require managerial attention.

Furthermore, the dynamic and regression analyses revealed significant causal relationships among several SCQM criteria. The results showed that improvements in certain criteria can generate cascading positive effects on other criteria, thereby amplifying the overall impact on supply chain performance. For instance, strengthening supply chain quality strategies was found to significantly influence customer and market focus as well as supplier quality management.

The proposed framework provides managers with a structured decision-support tool for identifying critical improvement points and prioritizing strategic actions. By combining literature-based indicators, expert knowledge, and empirical validation using historical company data, the model offers a practical approach for analyzing and improving supply chain performance in complex manufacturing environments such as the railway industry.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this book chapter.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used OpenAI's tool Chat GPT in order to edit and write some parts of this book chapter. After using this service, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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