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RELATIONSHIPS BETWEEN MANAGERIAL CONCEPTS IN INLAND TRANSPORT COMPANIES: A FUZZY-DEMATEL APPROACH

Summary. The axiom that the efficacy of supply chain entities is inextricably tied to the adoption of an appropriate management system is widely acknowledged. At the heart of such a system are managerial concepts. There is abundant literature with a variety of theories, concepts, methods, and tools aimed at managerial enhancement. However, there is a dearth of specific recommendations for their application, an understanding of their interdependencies, or discerning which concepts are causative and which are resultant in nature. The heterogeneous functions of supply chain participants preclude a universal best-practice array of these managerial concepts. By focusing on the pivotal role of inland transport firms within the supply chain, this study delineates an array of managerial concepts apt for such enterprises, employing the fuzzy-DEMATEL method. This study's contribution is encapsulated in the identification of the structural, relational, and hierarchical configuration of managerial concepts that bolster the decision-making framework of inland transport management.

1. INTRODUCTION

Among the complexities of supply chains, distinct entities such as maritime container terminals, shippers, shipping lines, inland transport companies, and freight forwarders are identified [1]. Inland transport companies, acting as multimodal transport operators, emerge as pivotal collaborators affecting the network and its comprehensive functionality [2]. Occasionally, these entities assume the role of agents, orchestrating transport logistics efficiently and safely on behalf of the hiring entities, aligning with the legal frameworks governing multimodal transport services not directly associated with cargo owners. Moreover, numerous inland transport entities undertake the responsibilities of freight forwarders in the market of transport services.

The integral position held by inland transport companies within supply chains suggests that their operational disruptions could detrimentally impact the collaborative dynamics and the supply chain's aggregate efficacy [3]. Hence, the establishment of an effective management framework for these companies is imperative. This framework necessitates foundational managerial concepts to guide its structure or configuration.

A thorough examination of existing literature, set to be elaborated in the subsequent chapter, reveals a variety of managerial concepts, highlighting the profound influence of appropriate management principles on organizational performance, a widely acknowledged notion [4-7]. Nonetheless, the literature offers scant guidance on the optimal assortment of managerial concepts tailored for inland transport companies, including their interrelations, hierarchical significance, and the determinants of their cause-and-effect dynamics. The approach for delineating the interconnections among managerial concepts is a pioneering endeavor in scholarly research.

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Given the lack of clarity on which managerial concepts are most effective for inland transport companies, it is crucial to address the following questions:

- What is the optimal selection of managerial concepts for these companies?
- How do these concepts interrelate?
- What are their hierarchical significances?
- What are the determinants of their cause-and-effect dynamics?

As these questions remain open, it should be clarified that conflicts of interest can arise due to the different roles played within supply chains, making it difficult to identify and propose the single best set of managerial concepts for all supply chain stakeholders. This situation implies the selection of a relatively homogenous group of companies for this reason. Therefore, due to the significant role of inland transport companies in Poland within supply chains, they were selected as the research objects for this study.

The purpose of this research is to calculate and determine the relationships between managerial concepts in inland transport companies using a fuzzy-DEMATEL approach. This approach also includes constructing a heat map that presents even the weakest relations, followed by ranking and identifying causal and effectual groups of managerial concepts. Although this research presents results obtained from the investigation of Polish inland transport operators, the proposed structure of managerial concepts is not limited to them, as it may be applied by other EU inland transport companies due to the similar social and business regulations within the EU.

The results meeting the research aim are presented in this paper, which is structured as follows. The next section is dedicated to the literature review, followed by methodology issues. The fourth section presents the obtained results of the research, after which discussions, research limitations, further research directions, and conclusions are formulated.

2. LITERATURE REVIEW

Inland transport companies face a multitude of problems, many of which have management-related aspects. When seeking solutions, these companies often look for a set of managerial ideas, concepts, methods, tools, etc. However, due to the high level of complexity of managerial issues, which also change dynamically over time, managers of these companies may not always expect to be provided with solutions that are suitable for their current issues and likely to be appropriate in the future. To avoid this problem, managers seek more general solutions, propositions, concepts, or frameworks that they could resolve with their experience and adapt to their specific problem situations.

The literature review has uncovered numerous managerial concepts applicable to inland transport companies for resolving their issues. Notably, this investigation also recognizes that global crises, including the COVID-19 pandemic, the conflict in Ukraine, and initiatives towards a sustainable economy to counteract global warming, have profoundly affected transportation activities. For instance, the reduction in global trade during the COVID-19 pandemic surpassed the downturn witnessed during the preceding financial crisis [8]. Specifically, the pandemic severely disrupted the operations of Polish inland transport companies in the first half of 2020 [9]. These real-world crises have subsequently influenced both management theory and practice, precipitating the development and rising prominence of new managerial concepts.

Risk management has emerged as a critical area, especially in light of the fundamental shift in addressing risk issues necessitated across various sectors, including inland transport enterprises [10]. Before the pandemic, risk management predominantly focused on addressing terrorism as well as legal and political instabilities. However, the post-COVID-19 era has underscored its significance, with an emphasis on mitigating the adverse outcomes of unforeseen events and risk control [4, 7]. The advent of blockchain technology-based solutions for risk management within supply chains and organizations has been noted [11].

The exigency of maintaining security and safety levels in inland transport operations has led to the recognition of integrated and coordinated management as vital under heightened risk conditions.

Ensuring the safety of both cargo and transportation means, while also considering the potential for cyberattacks, is imperative [12]. Strategic and operational management for inland transport companies, although well-established in management discourse, now stresses the importance of configuring organizational resources and structures for enhanced adaptability to unpredictable changes, whereas operational management aims to refine resource utilization and curtail transportation times [13]. These shifts are also integral to risk and change management perspectives [14].

Furthermore, knowledge and human resources management are deemed essential in inland transport company management. Emphasis is placed on utilizing knowledge to boost organizational efficiency and performance with a focus on human resources development to secure a competitive edge [6].

In the context of climate change, environmental management has gained importance, especially as inland transport companies grapple with stringent green transport mandates and emission regulations [15]. Some studies suggest potential improvements in the environmental performance of these companies and affirm a positive correlation between executive support and green supply chain management adoption [16].

Lastly, process management is crucial for any organization, including inland transport companies, underscoring that no transport activity can proceed without systematic processes. It significantly influences operational performance and the myriad facets of inland transport operations [17]. An evaluation of process maturity in supply chains reveals how systematically processes are defined and managed. Processes integrated into operational and strategic planning emanate from internal knowledge [18], advocating for a process-oriented management approach aligned with organizational activities [6].

The literature review suggests that all of the managerial concepts presented above could be proposed for use by inland transport operators. However, the existing literature does not verify this, and specific propositions tailored to this group of companies are lacking, creating a literature gap. Therefore, the research problem lies in verifying literature propositions by empirical study to discover the proper set of related managerial concepts for application by inland transport companies. Once these relationships are discovered and the appropriate structure of managerial concepts is proposed, it can be considered as added value for both theory and practice.

3. RESEARCH METHODOLOGY

This study explores the connections between managerial concepts in inland transport operations by investigating how these concepts are utilized in practice, often based on managerial discretion. For a more objective analysis, the fuzzy-DEMATEL technique was identified as the preferred method owing to its capabilities to quantify the impact and causal relationships among factors, as seen in its application across various domains, including supply chain analysis and risk evaluation [19-21].

Originally established in the 1970s, DEMATEL helps depict factor influences and determine cause-effect dynamics. This methodology is well-established, thus bypassing the need for detailed recounting in this context. However, specific considerations regarding its application in this study are noteworthy, especially the emphasis on qualitative insights from a select group of experts, which can be as few as three to 10 in standard practices [22].

This research focused on 180 members of the Polish Association of Logistics and Forwarding, narrowed down to 140 entities deeply engaged in inland transport. Despite DEMATEL's low requisite for participant numbers, all 140 entities were surveyed to maximize the response rate and enrich the data's quality. For data collection, a structured questionnaire was deployed via email. Respondents rated the influence of various management concepts on each other on a scale from 0 (no influence) to 4 (very high influence), enabling a comprehensive analysis of the managerial dynamics within these companies (Table 1). The simplicity of the questionnaire's structure was intended to augment the probability of obtaining the highest possible return rate of correctly completed surveys. Experts were invited to impart their professional evaluations regarding the impact of individual factors upon each other within the proposed model on a scale ranging from 0 (no influence) to 4 (very high influence). Thus, the attribution of a score of 0 in the query pertaining to the influence of factor f1 on f2, for instance, signifies that factor f1 does not exert an impact on factor f2.

Table 1

Concepts of management used in this research

| Factors | Managerial concepts |
|---------|--|
| f1 | Process management |
| f2 | Risk management |
| f3 | Strategic and operational management |
| f4 | Knowledge and human resources management |
| f5 | Customer relations management |
| f6 | Environmental management |
| f7 | Safety and security management |
| f8 | Change management |

Source: own elaboration

In May 2023, the initial distribution of questionnaires to the 140 targeted companies resulted in four completed returns, with an additional 12 responses following a second outreach in June 2023, culminating in 16 responses in total. Despite a seemingly modest response rate of 11%, the input was deemed significant, originating from key organizational figures like management board members, CEOs, and owners, who are well-versed in managerial decision-making.

Acknowledging the potential subjectivity in expert feedback, which might affect the precision of DEMATEL outcomes, this research incorporated fuzzy set theory elements to enhance objectivity, leading to the adoption of the fuzzy-DEMATEL methodology in the analysis [23].

The process involved collecting sixteen matrices on which each respondent provided weighted assessments of management concepts through pairwise comparisons. These weights were then transformed into triangular fuzzy numbers using a triangular membership function, resulting in a set of fuzzy numbers labeled “a,” “b,” and “c” for the lower, medium, and upper bounds of the fuzzy sets, respectively (Formula 1) [23]. The application of a fuzzy linguistic scale in this study facilitated this conversion and the subsequent analysis (Table 2).

$$u_A(x) = \begin{cases} 0; & x < a \\ \frac{(x-a)}{(b-a)}; & a \leq x \leq b \\ \frac{(x-c)}{(b-c)}; & b \leq x \leq c \\ 0; & x > c \end{cases} \quad (1)$$

Table 2

Fuzzy linguistic scale

| Linguistic term | Influence grades/weights | Triangular fuzzy number |
|---------------------|--------------------------|-------------------------|
| Very high influence | 4 | (0.75, 1, 1) |
| High influence | 3 | (0.50, 0.75, 1) |
| Low influence | 2 | (0.25, 0.50, 0.75) |
| Very low influence | 1 | (0, 0.25, 0.5) |
| No influence | 0 | (0, 0, 0.25) |

Source: [23]

The fuzzy numbers were transformed into crisp values through the best non-fuzzy performance method, a process articulated in Formula (2).

$$BNP = \frac{(c-a)+(b-a)}{3} + a \quad (2)$$

The research aimed to extend the application of managerial concepts beyond a singular transport firm to a broader spectrum. This necessitated the transformation of the initially obtained defuzzified crisp values into a more generalized form [23]. Consequently, the subsequent phase involved computing the mean of these crisp values, derived from the same 16 matrices, to produce a consolidated matrix Z . This matrix encapsulated the average weights, delineating the interrelations among the eight management concepts across all participants.

However, these average values in matrix Z remained in the form of crisp values, necessitating further standardization. This led to the development of a standardized fuzzy matrix X , established through specific computational methods detailed in Formulas 3 and 4, to further refine the analysis and enhance its applicability and precision in explaining management concept relationships [23].

$$X = S \times Z, \quad (3)$$

where:

X – standardized fuzzy matrix of direct relationships,

$$S = \frac{1}{\text{Max}_{1 \leq i \leq n} \sum_{j=1}^n Z_{ij}}, \quad (4)$$

Z – matrix of relationships in the form of average crisp values

While matrix X shed light on the bilateral relations among different managerial concepts, it depicted merely a fraction of the whole picture, lacking a comprehensive table that would encapsulate the overall significance and interconnectivity of these concepts, including their causal and effectual roles.

To rectify this, the subsequent phase of research involved computing the total fuzzy impact matrix T utilizing Formula 5. In this formula, the symbol I denotes the identity matrix characterized by zeros along its diagonal and ones elsewhere, facilitating a holistic analysis of the managerial concepts' interactions and influences.

$$T = X(I - X)^{-1}. \quad (5)$$

The total significance indicator (TS_{ij}) and total relation indicator (TR_{ij}) for individual management concepts were computed based on Formulas 6 and 7 [5, 20].

$$TS_{ij} = R_{ij} + C_{ij} = \sum_{j=1}^n t_{ij} + \sum_{j=1}^n t_{ij} \quad (6)$$

$$TR_{ij} = R_{ij} - C_{ij} = \sum_{j=1}^n t_{ij} - \sum_{j=1}^n t_{ij} \quad (7)$$

where:

R_{ij} – sum of all values in rows in the matrix T

C_{ij} – sum of all values in columns in the matrix T

The total fuzzy impact matrix T was depicted through a heat map to ensure an intuitive visualization, making it easier to discern all levels of relationships, including the most minor ones. The total relation indicator (TR_{ij}) was instrumental in discerning the causative and resultant attributes of the managerial concepts. Together with the total significance indicator (TS_{ij}), they were crucial in establishing a hierarchy among the managerial concepts, which, in turn, served as a basis for developing strategic advisories for inland transport enterprises.

4. RESULTS

In the primary dispatch of surveys to 140 entities in May 2023, four of them provided completed responses. A subsequent solicitation in June 2023 yielded contributions from another dozen participants. Consequently, a total of 16 responses was garnered. Despite the seemingly scant return rate of 11%, the caliber of the respondents—those in directorial and executive positions, such as board members, CEOs, and proprietors – renders the data of considerable worth.

Concerning the methodology, the subjective nature of expert responses has been cited as potentially compromising precision. The incorporation of fuzzy set theory was deemed pertinent to counteracting this; thus, the fuzzy-DEMATEL method was utilized in this investigation. Subsequent calculations birthed 16 matrices indicating the perceived importance of management concepts, with pairwise comparisons elucidating the dynamics between them. The resultant total fuzzy impact matrix T ,

visualized through a heat map (Table 3), delineates the interaction strength of each managerial concept with respect to others. For instance, the intersection at the first row and the second column shows a value of 0.7049, signifying a substantial influence of 'f1' (process management) on 'f2' (risk management).

Further analysis of matrix T led to an integrated assessment, incorporating the total significance (TS_{ij}) and relation (TR_{ij}) indicators, revealing insights into the concepts' causal or effectual tendencies and forming the basis of a dual-ranking system (Table 4).

Table 3

Total fuzzy impact matrix T (relationship values)



Source: own elaboration using the Python programming language

In an analysis, it would be inferred that strategic and operational management holds primacy in terms of the total significance indicator (TS_{ij}), as indicated by its highest value of 8.9892. The computation of TS_{ij} incorporates both the row (R_{ij}) and column (C_{ij}) data for a given concept from matrix T , implying an additive model in which R_{ij} represents the cumulative influence of a management concept across all other concepts and C_{ij} embodies the aggregated impact received from all other concepts. Thus, TS_{ij} is a bidirectional measure of significance in the managerial context.

Further examination reveals that process management, with a TS_{ij} of 8.9486, and risk management, with a TS_{ij} of 8.7471, follow closely behind strategic and operational management in terms of significance. Notably, process management is distinct in possessing the highest total relation indicator (TR_{ij}) of 0.9767, signaling a causal nature. This indicates that process management acts as a driving force exerting influence over other concepts as opposed to being predominantly influenced by them.

Contrastingly, concepts with a negative TR_{ij} are denoted as effectual, suggesting that they are more influenced by other concepts than influencing. Within this classification fall the concepts of risk, environmental, strategic and operational, customer relations, and safety and security management. The dichotomy of causal and effectual concepts delineates a framework within which managerial strategies can be optimized based on their potential to influence or be influenced within the organizational milieu.

Table 4

Total assessment of managerial concepts

| Factors | Managerial concepts | Total significance indicator (TS_{ij}) | Ranking according to significance | Total relation indicator (TR_{ij}) | Ranking according to relation | Causal or effectual character |
|---------|--|--|-----------------------------------|--|-------------------------------|-------------------------------|
| f1 | Process management | 8.9486 | 2 | 0.9767 | 1 | Causal |
| f2 | Risk management | 8.7471 | 3 | -0.0949 | 4 | Effectual |
| f3 | Strategic and operational management | 8.9892 | 1 | -0.2291 | 6 | Effectual |
| f4 | Knowledge and human resources management | 8.2139 | 5 | 0.0651 | 2 | Causal |
| f5 | Customer relations management | 6.8128 | 7 | -0.3527 | 7 | Effectual |
| f6 | Environmental management | 4.7113 | 8 | -0.2001 | 5 | Effectual |
| f7 | Safety and security management | 8.2918 | 4 | -0.6724 | 8 | Effectual |
| f8 | Change management | 8.1423 | 6 | 0.5072 | 3 | Causal |

Source: own elaboration

Subsequently, it is plausible to construct two hierarchical rankings of managerial concepts predicated on TS_{ij} and TR_{ij} values. The former ranks concepts from the most to least significant, thereby providing insights into which management areas demand prioritization. The latter, incorporating the causal-effectual dichotomy, offers a nuanced perspective of the directional influence dynamics among the concepts. The disparity between these rankings may be a fertile ground for scholarly discussion, particularly in exploring the implications of managerial influence on organizational performance and strategic planning.

This analytical interpretation does not deviate from the essence of the data provided but reiterates the findings through a scientific lens, emphasizing the methodological approach and potential implications for organizational strategy within the context of inland transport companies. It encapsulates the data's indicative nature concerning the bidirectional significance and influence amongst managerial concepts.

5. DISCUSSION

This research raised the problem of the interpretation of two rankings of managerial preferences presented in Table 4. Per the research aim of gaining a better insight into the problem, Table 4 has been formatted as Table 5, which indicates that the management solutions considered are different. Thus, a question arises, especially from the practice side, about the best practices that can be recommended for inland transport operators. It seems to be a methodological as well as a managerial issue.

Methodologically, the interpretation of the total significance indicator (TS_{ij}) has achieved scholarly consensus and has been characterized as a metric indicating the relative importance of a criterion [18]. A higher TS_{ij} denotes greater importance, necessitating prioritization in evaluative processes [5, 18, 24]. However, the literature lacks a clear consensus regarding the total relation indicator (TR_{ij}), with references to its use in assessing the reciprocal effects of criteria or their net contribution to the system [24] and some asserting that positive TR_{ij} values denote a high impact on other criteria [25]. This has the potential to conflate significance, impact, and priority across both indicators, leading to ambiguity.

In the authors of this article's opinion, another deep insight into the research findings is required. According to them, the main question formulated for the respondents was based on which concept they considered more important compared to another, not on the relationships connecting the eight concepts. Therefore, the ranking based on total significance indicators (TS_{ij}) was prioritized over the ranking based on total relation indicators (TR_{ij}), as the latter is the result of a calculation method – the Fuzzy-DEMATEL technique – and, thus, is of a supportive nature.

Table 5

Rankings of managerial concepts

| Managerial concepts ranked according to the total significance indicator (TS_{ij}) | Managerial concepts ranked according to the total relation indicator (TR_{ij}) | Causal or effectual character |
|--|--|-------------------------------|
| 1) Strategic and operational management | 1) Process management | Causal |
| 2) Process management | 2) Knowledge and human resources management | Causal |
| 3) Risk management | 3) Change management | Causal |
| 4) Safety and security management | 4) Risk management | Effectual |
| 5) Knowledge and human resources management | 5) Environmental management | Effectual |
| 6) Change management | 6) Strategic and operational management | Effectual |
| 7) Customer relations management | 7) Customer relations management | Effectual |
| 8) Environmental management | 8) Safety and security management | Effectual |

Source: own elaboration

The most significant concept appeared to be strategic and operational management, followed by process management, and risk management. Additionally, they should be allocated to casual and effectual groups of concepts, meaning that the first one impacts the last group and that process management has the greatest impact on the effectual concepts.

6. CONCLUSIONS, LIMITATIONS, AND FURTHER RESEARCH DIRECTIONS

Based on a meticulous analysis of the research findings and the ensuing dialogue within the discussion segment, one could assert that strategic and operational management is a preeminent concept. The decisions pertaining to analysis, planning, organization, motivation, and control within this domain ought to be effectuated or augmented through diligent application of process management. To elaborate, an integrated suite of all eight managerial concepts should be instituted as the foundational infrastructure of management systems within inland transport companies, with particular reference to those under the purview of the study.

In this architecture of management, it is envisioned that strategic and operational management synergizes with risk management, safety and security management, customer relations management, and environmental management. This coalition is envisaged to be orchestrated through the conduits of process management, buttressed by knowledge and human resources management as well as change management. Not only does such a recommendation extend to the domestic Polish inland transport firms, owing to the analogous socio-economic conditions prevailing within the country, but it also posits viability for adoption by analogous enterprises within other European Union member states. Despite variances in the socio-economic climates, the commonality in business operation frameworks within the EU milieu provides a conducive environment for such managerial constructs.

The prerogative to adopt this scientifically substantiated management constellation is at the discretion of individual managers. Nonetheless, they are endowed with an empirical model that is

pertinent to their managerial tasks. The insights provided by this study not only bolster theoretical paradigms but also enhance the pragmatic comprehension of inland transportation's role within the larger ambit of supply chain management.

The research methodology delineated herein further serves as a heuristic device, offering a scaffold upon which comparable inquiries could be modeled, serving as a touchstone for analogous analyses across diverse cohorts of supply chain stakeholders.

The primary circumscription of this inquiry stems from its concentration on Polish inland transport firms, representing an inaugural effort to map the interconnections amongst various managerial concepts within this domain. Notwithstanding the justification to focus on a uniform stakeholder group, consequent to the unique operational attributes of inland transport, it is deemed prudent to corroborate these research outcomes with data from a broader spectrum of firms. Prospective research trajectories should extend this study to encompass a broader constellation of supply chain participants across different areas in Europe.

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