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A Hybrid Approach to Logistics Optimization: Combining DEMATEL with Classical Transportation Algorithms in the Steel Industry

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Abstract: Transportation system is one of the major parts of the supply chain in an industry. Efficient route selection can substantially reduce both operational expenses and travel time. This study investigates the most efficient way for transporting raw materials from supply centers to warehouses, by calculating the total cost by different methods, such as Northwest Corner Method, Least Cost Method, and Vogel Approximation Method, for a renowned steel manufacturing company in Bangladesh. Further we identified the most significant factors that affect transportation, by applying the Decision Making Trial and Evaluation Laboratory (DEMATEL) method, which is one of the Multi-Criteria Decision-Making (MCDM) techniques. Expert opinions, in-depth data analysis, and data visualization provide a clear idea about the current situation of these circumstances. We found out the relationships between key criteria, such as cause effect factors, and how they impact each other in increasing the overall cost of the transportation process. Finally, we recommended some practical and applicable suggestions for solving the issues that hamper the transportation process most, for ensuring a smooth supply chain.

Keywords: Transportation, optimization, MCDM, Steel Manufacturing.

1. Introduction:

Efficient transportation plays a significant role in modern supply chain and logistics management. It often affects the operational costs, service quality and impedes long-term economic sustainability. The goal of transportation problems is to balance supply, demand, and transportation costs between various sources and destinations while minimizing distribution costs. In industries like steel manufacturing companies rely heavily on raw material supply. So, transportation challenges often lead them to cost escalation, delivery delays and disruptions across the production cycle. The rising complexities of supply networks, the optimization of transportation routes has become an essential area of study for ensuring competitiveness and resilience.

There are some traditional approaches like- Northwest Corner, Least-Cost and Vogel Approximation methods. These provide traditional approaches to minimize transportation costs. But real-world transportation problems extend beyond cost minimization as they are influenced by multiple co-related factors like unsuitable vehicle selection, traffic clogging, fluctuating fuel prices and infrastructural limitations. These factors make it difficult for decision-makers to identify root causes and implement actionable solutions. To address such complexities the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method under Multi-Criteria Decision-Making (MCDM) techniques is effective in identifying cause and effect factors within complex systems. DEMATEL is able to distinguish between cause factors (drivers) and effect factors (outcomes). In this paper, the data are taken a renowned steel manufacturing company that uses Ferrous scarp as the raw material. The data are verified by the industry experts. Different classical methods along with the DEMATEL method are applied to pick the most efficient and optimized way out. By the study 4 cause factors, 4 effect factors and two factors with equivalent results are found. By integrating traditional transportation models with MCDM analysis, the study identifies optimal cost-minimizing routes and deals with the factors that hinder or facilitate efficient transportation. Thus, the findings aim to provide actionable insights for logistics planners, supply chain managers and policy makers to make the right decision.

2. Literature Review:

Many research work has been conducted on the sector of transportation engineering. Logistical complexity, high transportation costs, need for an optimal strategy, imbalance in demand & supply cause big losses in business (Pate, May, 2020). In order to maintain a balanced transportation task, the supplier and the customer need to develop a regular and efficient communication process (Peter Malackýa, 2023). Poor packaging, insufficient tracking and monitoring, and lax administrative procedures are some of the major causes of shipping inefficiency, claims (Ahmad

Soimun*, 18 June 2025). The supplier must monitor the demand of the customer, while the customer must also keep track of the supply of the supplier (Peter Malackýa, 2023). There is also some research work that has been done on the cost comparison between two vehicles on the same route (Islam, 05-11-2020).In the real world, we have to deal with various facts such as road permeability, one-way roads, etc. We apply these facts as limiting conditions, which have also been attached to the upcoming section in this research (Peter Malackýa, 2023). Fluctuations in demand can pose challenges in terms of flexibility and the need to frequently reassess and adjust the transportation schedule to meet new requirements (Leavengood, June,2002).

Research on unintentional problems in transportation has also been conducted. According to studies on the risks associated with hazardous transportation, environmental factors and driver behavior are both important contributors to accidents, indicating the need for more robust safety protocols. The results show noteworthy trends in the frequency of accidents, especially the significance of comprehending accident causes to guide policy choices (University, March, 2025) **.** Enhancing safety culture through training, securing sustained financial investment, and strengthening governance frameworks are essential for improving the safety, efficiency, and sustainability of public transportation systems**.** A statistical optimization technique that models relationships between variables to identify optimal conditions, and conducted regression analysis, correlation coefficient analysis, factorial plot analysis, and contour plot analysis to validate the relationships among demand, production, and inventory levels (Jannatul Fardush Shorna, 05-11-2020)**.** Timely delivery, secure packaging, effective customer service and convenient payment options is important factors of logistics for better satisfaction of a customer (Imran Ahmed, 2024)**.** The distribution to the demand point from the factory operating in the Iron and Steel Sector is considered as the basic problem. Critical aspect of this problem is to use the single source transportation model, where all demand amounts are met from a single production center (ASKERBEYLİ, 2018). The movement of products from supply to demand points requires efficient use of transport routes like highways, waterways, and railways. (A, 2022). A hybrid approach consistently yields lower transportation costs compared to conventional methods, making it particularly beneficial for industries involved in logistics and supply chain management. Future research directions are suggested to address additional factors like delivery time and dynamic demand variations (Gupta, 2025).

In Bangladesh, much work has been done to optimize the supply chain of various products. Research highlights the importance of accurate forecasting for agricultural planning and decision-making for the supply chain of rice, which can lead to better resource utilization and improved profitability for farmers (Faiyaz Bin Mahmu, 2024). A study discussed the importance of green supply chain management (GSCM) in Bangladesh's textile and apparel industry (Md. Fahad Hasan Fahim, 2024). Another study tried to assess the external vulnerability of rice supply chain using

FMEA, Bishwanath Upazila, Sylhet, Bangladesh (Tasin A. Nahin, 2024). Price hiking of green chili also been examined in terms of supply chain (Muzahidur Rahman Chowdhury, 2024).

Overall, the previous works indicate that the overall efficiency of transportation depends not only on cost optimization but also on other factors like safety, sustainability, and adaptability to demand fluctuations. Still, only a few studies have integrated cost-minimizing transport models with multi-criteria decision-making approaches, our aim is to address that in this research.

3. Methodology:
All transportation algorithms has been described below:

1. Northwest-corner method.

Step 1: Assign as much as you can to the chosen cell. Then, remove the assigned amount from the corresponding supply and demand numbers.

Step 2: To show that no more assignments may be made in a row or column with zero supply or demand, cross it out. If a row and a column both net to zero at the same time, only cross out one of them, leaving the uncrossed-out row (column) with zero supply (demand).

Step 3: Stop if precisely one row or column remains uncrossed out. If not, go to the cell below if a row has been crossed out, or to the right if a column has just been crossed out. Proceed to step 1.

2. Least - Cost Method:

1. Locate the transportation table's smallest cost cell.

2. Give that cell as many units as you can without going over supply or demand.

3. Cross off rows or columns that are exhausted to reflect the remaining supply and demand.

4. Continue until all requirements and supplies are satisfied, guaranteeing viability.

3. Vogel Approximation Method:

Calculate penalties by taking the difference between the two lowest charges for each row or column.

Allocation Priority: In the row or column with the largest penalty, allocate resources to the cell with the lowest cost.

Compared to the basic method, error reduction reduces initial allocation errors. Near-Optimal Start: Offers a productive starting point for more optimization. (Taha)

Steps in DEMATEL Process:

Step 1: Create measuring scales and choose crucial defining characteristics.

In order to determine the characteristics and measuring scales for the degree of influence, we identified the various qualities of the potential effects based on expert opinions and literature. In order to determine the average matrix, we asked each expert and scholar we interviewed to use an integer score to assess the direct influence between any two factors. A score of 0 meant "no influence," a score of 1 meant "low influence," a score of 2 meant "medium influence," a score of 3 meant "high influence," and a score of 4 meant "extremely high influence."

Step 2: Create a direct-relation matrix X.

$$\begin{bmatrix} 0 & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & 0 \end{bmatrix}$$

The degree to which attribute i influences attribute j was denoted by Xij in the direct-relation matrix. The diagonal attribute in the direct-relation matrix X was set to 0, indicating that the degree of impact on itself was unaffected by the same influence option of the dimension component. This study determined the degree of influence between the various components and produced a direct association matrix after the experts who were interviewed completed the questionnaire.

Step 3: Establish normalized direct-relation matrix N.

This study calculated the greatest value in the direct-relation matrix by adding up all of the columns. The λ-value, which served as the normalization basis, was the reciprocal of the greatest value.
To obtain the final normalized direct-relation matrix N, the direct-relation matrix X was multiplied by the value of λ.

$N=\lambda X$

Step 4: Create the direct/indirect relation matrix T in step four.

The unit matrix I was used to produce the direct/indirect relation matrix T and the total relation matrix after the normalized relation matrix N was obtained.
Furthermore, matrix T offered details on the potential interactions between various factors. I was a unit matrix, meaning it had a diagonal value of 1 and other values of 0. Consequently, the matrix T of direct and indirect relations was:

$T=\lim_{k\to\infty(}N+N2+\cdots+Nk)=N(I-N)^{-1}$

Step 5: Calculate the values of D_i and R_j, and the influencing degree of the factors from direct/indirect relation matrix T

We defined tij as attribute i, j = 1, 2,…, n of the direct/indirect matrix T after getting it since it was important to determine the degree of influence and the impact of one attribute on the other attributes. Di was the total of row i, which stood for the total of all the other qualities that attribute i had an impact on. The total of row j, or the sum of characteristics I influenced by the other attributes, was denoted by Rj. Both direct and indirect effects were present in Di and Rj, which were derived from the direct/indirect matrix T.

Step 6: Calculate the prominence (D+R) and relation (D−R)

Step 7: Draw the cause-and-effect relationship diagram

The prominence (D+R) displayed the degree of the relationship between dimensions, the overall degree of impact, and the influence of the factor; the value of this could disclose the fundamental degree and connection of the factor. Furthermore, the degree of cause, or (D−R), indicated the degree of difference between the influence and the effect of the factor and demonstrated the strength of the influence and the influence of the dimensions.

The X-axis and Y-axis center points were used to divide the four quadrants. Diagrams showing cause-and-effect interactions simplify intricate relationships between variables and demonstrate how each affects the others. The horizontal axis (X) in this study is the prominence (D+R), while the vertical axis (Y) is the relation (D−R). (Shyr, 2022)

4. Research Framework:

4.1. Problem Statement:

Q1. How can the use of efficient transportation methods reduce costs in supplying raw materials and provide long-term economic benefits?

Q2. How can MCDM techniques like DEMATEL help identify the root causes of transportation-related problems in the supply chain?

Q3. Which problems are effects, and which fall under the category of causes?

4.2. Initial Scenario:

Raw Materials: Ferrous Scrap

Per Ton Ferrous Scrap Price: 60000 BDT

We have considered balanced portion of supply and demand here.

In a production season,

Supply= Demand= 200 tons

Number of warehouses: 4

Number of raw materials supplier centers: 3

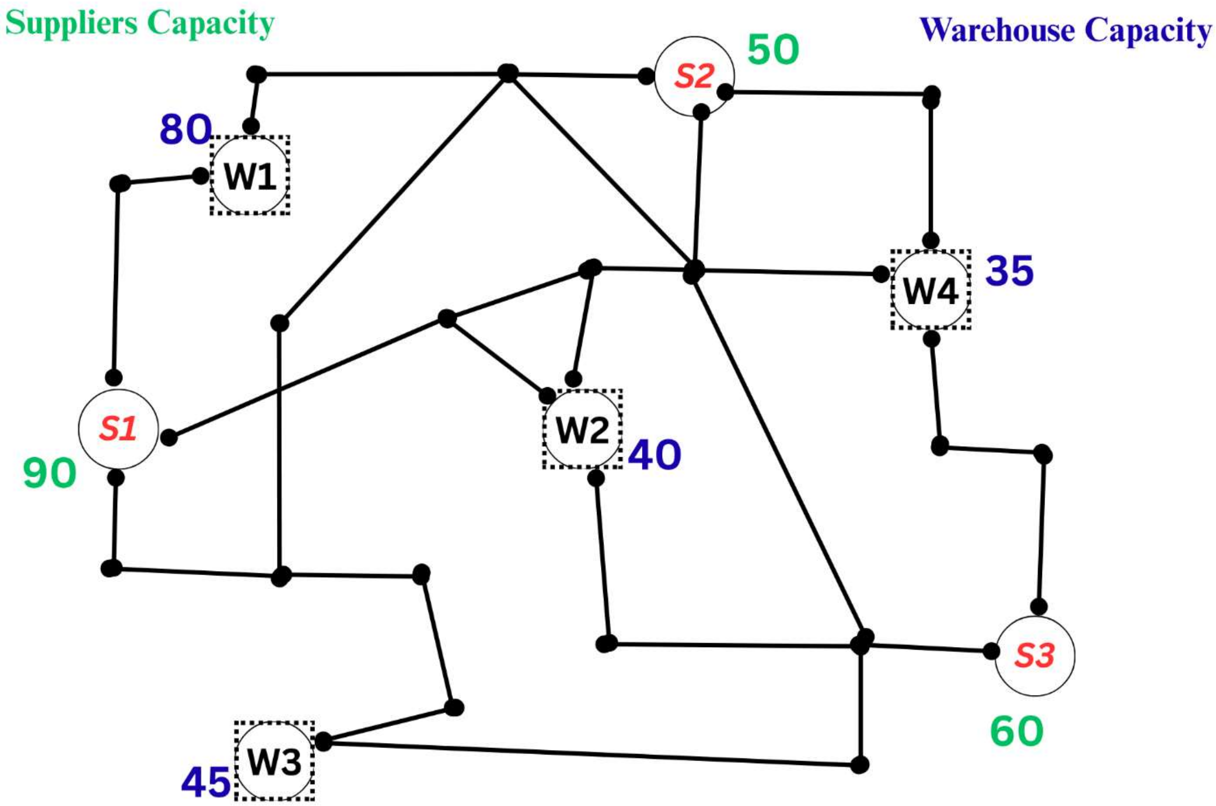

Fig.1: Transportation Chain among Warehouse and Suppliers for Raw Materials

Capacity:

Warehouse 1: 80

Warehouse 2: 40

Warehouse 3: 45

Warehouse 4: 35

Supplier 1: 90

Supplier 2: 50

Supplier 3: 60

4.3 Applying Transportation Algorithms:

Table.1: Resource Allocation by North-West Corner method

	W1	**W2**	**W3**	**W4**	*Supply*
S1	4000 80	6000 10	6200	8000	90
S2	5500	6400 30	8400 20	3600	50
S3	8500	5400	6300 25	5600 35	60
Demand	80	40	45	35	**200**

Total Cost: 80×4000 + 10×6000 + 30×6400 + 20×8400 +25×6300 + 35×5600 = *1093500 BDT*

Table.2: Resource Allocation by Least-Cost method:

	W1	**W2**	**W3**	**W4**	*Supply*
S1	4000 80	6000	6200 10	8000	90
S2	5500	6400	8400 15	3600 35	50
S3	8500	5400 40	6300 20	5600	60
Demand	80	40	45	35	**200**

Total Cost = 80×4000 + 40×5400 + 10×6200 + 15×8400 + 20×6300 + 35×3600 = *976000 BDT*

Table.3: Resource Allocation by Vogel Approximation Method:

	W1	**W2**	**W3**	**W4**	*Supply*
S1	4000 80	6000	6200 10	8000	90
S2	5500	6400 15	8400	3600 35	50
S3	8500	5400 25	6300 35	5600	60
Demand	80	40	45	35	**200**

Total Cost $= 80 \times 4000 + 15 \times 6400 + 25 \times 5400 + 10 \times 6200 + 35 \times 6300 + 35 \times 3600 = 959500$ *BDT*

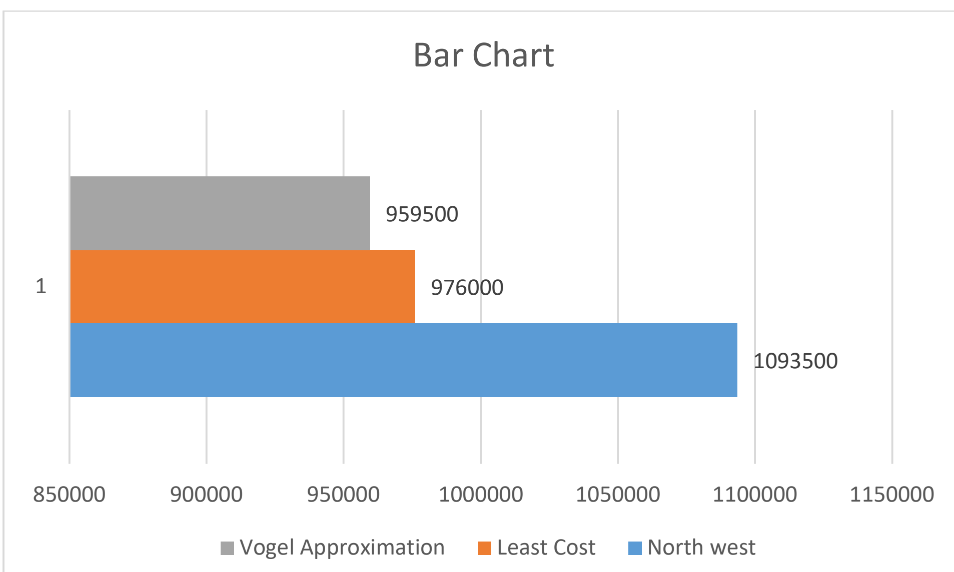

Fig.1: Bar Chart for Cost

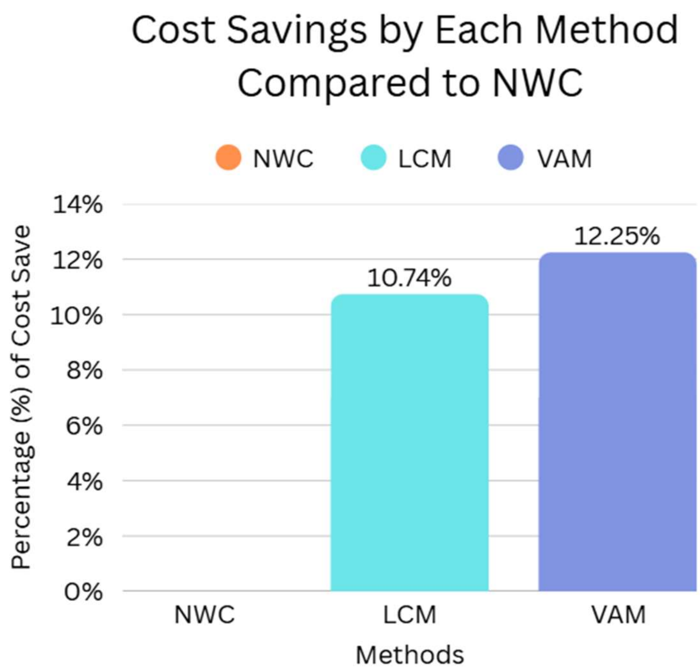

Fig.2: Cost Savings by Each Method Compared to North West Corner Method

4.4. Applying DEMATEL technique:

Table.4: Barriers in transportation within the supply chain for steel manufacturing raw materials

Problem No.	Problems/ Barriers	Description	Reference
P1	Unsuitable Vehicle Selection	Using the incorrect vehicles slows deliveries, increases costs and safety risks, and results in overloading, wasted space, and material damage.	(Ahmad Soimun*, 18 June 2025)
P2	High Transportation Cost	Shipping is costly due to fuel prices, tolls, and heavy vehicle maintenance, which	(Pate, May, 2020)

		lowers profits and drives up steel prices.	
P3	Road Parmeability	Fuel prices, tolls, and heavy vehicle maintenance make shipping expensive, which reduces profits and raises the price of steel.	(Peter Malackýa, 2023)
P4	Transportation Capacity	Weather-related delays, port backups, and a lack of trucks lead to shortages of materials, which halt production and damage supply chains.	(Xiaoyan Qi1, 2025)
P5	Road Condition	Trucks and cargo are harmed by poor road conditions (potholes, narrow lanes), which also slow shipments.	observation
P6	Traffic Jam	Unpredictable delays and fuel waste are caused by congestion in ports and industrial areas.	observation
P7	Unbalanced Supply Demand	Shortages or idle vehicles result from a mismatch between material volumes and transport capacity (trucks/ships).	observation
P8	Fuel Cost Fluctuation	Budgeting is challenging due to fluctuating fuel prices, as unexpected	observation

		cost increases reduce earnings.	
P9	Delay in Delivery	Production schedules are disrupted by the cumulative effects of other barriers, such as capacity and traffic.	observation
P10	Security Risk	Costs are increased when valuable raw materials, like scrap metal, are stolen or damaged in transit.	observation

Table.5: Profile of Experts:

Experts	**Experience Level**	**Professional Role**
1	4 years	Executive Supply Chain(Steel Manufacturing Company)
2	12 years	Deputy Managing Director(Overseas Operations & Logistics)
3	7 years	Freight Movement Expert
4	13 years	Professor (Supply Chain & Operations Management)
5	3 years	CRM Analyst Ocean Freight
6	7 years	Associate Professor (Department of Industrial & Production Engineering)
7	5 years	Supply Chain Leader (MNC)
8	5 years	Logistic Manager

Table.6: Comparison scale of DEMATEL method

Numeric Value	Definition
0	No influence

1	Very low influence
2	Low influence
3	High influence
4	Very high influence

Table.7: Direct relation matrix with 8 expert's opinion in order:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	{0,0,0,0,0,0,0,0}	{3,2,1,3,2,3,1,2}	{1,3,2,1,1,0,2,1}	{2,1,2,2,3,1,0,2}	{1,0,2,1,1,0,1,1}	{2,1,2,1,2,1,0,2}	{1,1,2,1,0,1,0,1}	{3,1,2,3,1,2,3,2}	{3,2,1,3,2,3,1,2}	{0,1,0,1,0,0,1,0}
P2	{2,2,1,3,1,2,1,2}	{0,0,0,0,0,0,0,0}	{1,3,2,1,2,3,2,1}	{3,2,3,2,3,1,2,3}	{1,3,2,1,0,1,2,3}	{1,2,3,2,1,2,3,1}	{3,1,2,3,1,2,3,1}	{4,3,2,3,3,1,3,2}	{2,3,2,2,3,2,3,2}	{1,1,2,1,2,1,0,1}
P3	{2,1,0,2,0,1,1,2}	{3,1,1,2,1,3,2,1}	{0,0,0,0,0,0,0,0}	{3,3,2,3,3,2,3,2}	{1,2,3,2,2,3,1,2}	{3,2,3,2,3,2,3,2}	{1,1,2,1,2,1,2,1}	{1,2,1,1,2,1,2,1}	{2,2,3,2,3,2,3,2}	{1,2,1,1,2,1,2,1}
P4	{3,2,3,2,1,3,2,2}	{2,3,2,3,2,1,2,3}	{3,2,3,2,3,2,3,2}	{0,0,0,0,0,0,0,0}	{2,1,2,1,2,1,2,1}	{2,3,2,3,2,3,2,3}	{2,3,1,2,3,2,3,1}	{1,2,1,2,1,2,3,1}	{4,3,2,3,2,3,2,3}	{1,0,0,0,0,0,0,0}
P5	{1,1,2,1,2,1,2,1}	{1,2,1,2,1,2,1,2}	{2,1,2,3,2,1,2,1}	{1,2,1,2,3,2,1,2}	{0,0,0,0,0,0,0,0}	{3,3,2,3,2,3,2,3}	{1,2,1,2,1,2,1,2}	{1,2,2,1,2,1,2,1}	{3,2,3,2,3,2,3,2}	{1,0,1,0,1,0,1,0}
P6	{1,1,0,1,0,1,0,1}	{3,2,3,2,3,2,3,2}	{3,2,3,1,2,3,2,3}	{2,1,2,1,2,1,2,1}	{2,3,2,3,2,3,2,3}	{0,0,0,0,0,0,0,0}	{1,2,3,1,2,3,1,2}	{2,2,3,2,3,2,3,2}	{3,3,2,3,2,3,1,2}	{1,2,1,2,1,2,1,0}
P7	{1,2,1,2,1,0,1,2}	{2,1,0,2,1,2,1,0}	{2,1,2,1,2,1,2,1}	{3,2,3,2,3,1,2,3}	{1,2,1,2,1,2,1,2}	{2,1,2,1,2,1,2,1}	{0,0,0,0,0,0,0,0}	{2,3,2,3,2,3,2,3}	{3,2,3,2,3,2,3,2}	{1,1,0,1,0,1,0,1}
P8	{2,1,2,1,2,1,2,1}	{3,2,1,2,3,2,1,2}	{2,1,2,1,2,1,2,1}	{1,2,1,2,1,2,1,2}	{2,1,2,1,2,1,2,1}	{2,3,2,3,2,3,2,3}	{2,1,2,1,2,1,2,1}	{0,0,0,0,0,0,0,0}	{3,2,3,2,3,2,3,2}	{1,2,1,2,1,2,1,2}

P9	{3,2,1,3,2,3,2,1}	{3,2,3,2,3,1,2,3}	{2,3,2,3,2,3,2,3}	{3,4,3,2,3,2,3,3}	{3,2,3,4,3,2,3,4}	{2,3,2,3,2,3,2,3}	{3,2,3,4,3,2,3,2}	{3,2,3,2,3,2,3,2}	{0,0,0,0,0,0,0,0}	{3,2,3,2,3,2,3,2}
P10	{1,2,1,2,1,2,1,2}	{1,2,1,2,1,2,1,2}	{1,2,1,2,1,2,1,2}	{0,1,0,1,0,1,0,1}	{1,2,1,2,1,2,1,2}	{1,2,1,2,1,2,1,2}	{1,2,1,2,1,2,1,2}	{1,2,1,2,1,2,1,2}	{2,1,2,1,2,1,2,1}	{0,0,0,0,0,0,0,0}

Table.8: Direct relation matrix with 8 expert's opinions average:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	0	2.12	1.38	1.5	1	1.38	1	1.94	2.12	0.38
P2	1.63	0	1.63	2.5	1.5	1.88	2.12	2.63	2.12	1.13
P3	1.13	1.63	0	2.88	1.88	2.63	1.38	1.13	2.38	1.13
P4	2	2.38	2.5	0	1.88	2	2.25	1.5	3	0
P5	1.38	1.5	2.13	1.88	0	2.75	1.5	1.38	3	1
P6	1.25	2.5	2	1.25	2.5	0	1.63	2	2.63	1.38
P7	1.06	1	1.63	2.38	1.06	1.5	0	2.38	2.63	1
P8	1.5	2.13	1.5	1.13	1.5	2.38	1.5	0	2.38	1.5
P9	2.13	2.38	2.38	2.88	2.63	2.38	2.63	2.38	0	2.25
P10	1.5	1.5	1.5	0.5	1.5	1.5	1.5	1.5	1.5	0

Maximum value of Row: 21.88

Table.9: Normalized value of matrix (N):

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	0	0.097	0.063	0.069	0.046	0.063	0.046	0.088	0.097	0.017
P2	0.074	0	0.075	0.114	0.068	0.086	0.097	0.12	0.097	0.052
P3	0.052	0.074	0	0.132	0.086	0.12	0.063	0.052	0.109	0.052
P4	0.091	0.109	0.114	0	0.086	0.092	0.103	0.069	0.137	0
P5	0.063	0.068	0.097	0.086	0	0.126	0.069	0.063	0.137	0.046
P6	0.057	0.114	0.091	0.057	0.126	0	0.074	0.091	0.12	0.063
P7	0.049	0.046	0.074	0.12	0.049	0.068	0	0.12	0.12	0.046

P8	0.068	0.097	0.068	0.052	0.068	0.109	0.068	0	0.109	0.068
P9	0.097	0.109	0.109	0.132	0.12	0.109	0.12	0.109	0	0.103
P10	0.068	0.068	0.068	0.023	0.068	0.068	0.068	0.068	0.068	0

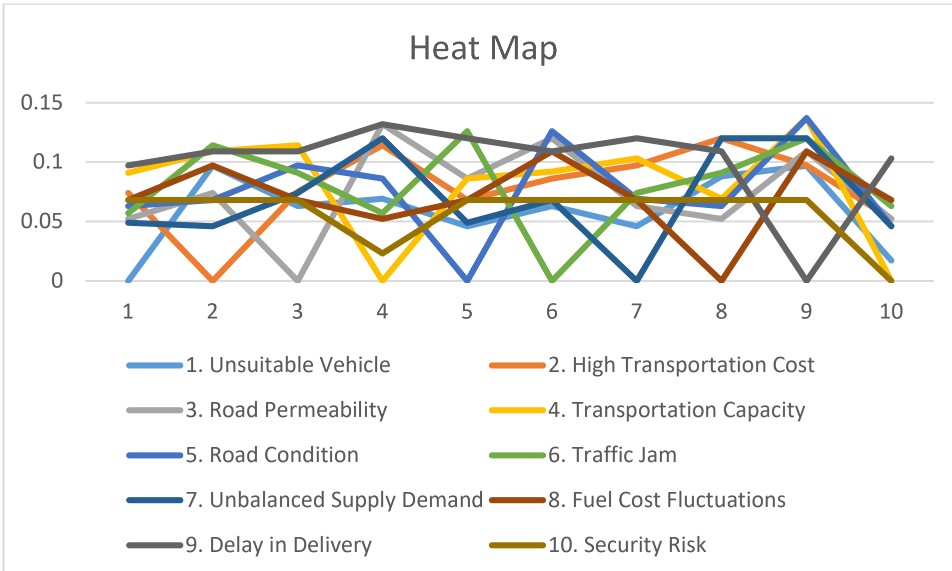

Fig.3: Normalized Expert Opinion Value's Heatmap

Table.10: I-N:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	1	-0.097	-0.063	-0.069	-0.046	-0.063	-0.046	-0.088	-0.097	-0.017
P2	-0.074	1	-0.075	-0.114	-0.068	-0.086	-0.097	-0.12	-0.097	-0.052
P3	-0.052	-0.074	1	-0.132	-0.086	-0.12	-0.063	-0.052	-0.109	-0.052
P4	-0.091	-0.109	-0.114	1	-0.086	-0.092	-0.103	-0.069	-0.137	0
P5	-0.063	-0.068	-0.097	-0.086	1	-0.126	-0.069	-0.063	-0.137	-0.046
P6	-0.057	-0.114	-0.091	-0.057	-0.126	1	-0.074	-0.091	-0.12	-0.063
P7	-0.049	-0.046	-0.074	-0.12	-0.049	-0.068	1	-0.12	-0.12	-0.046

P8	-0.068	-0.097	-0.068	-0.052	-0.068	-0.109	-0.068	1	-0.109	-0.068
P9	-0.097	-0.109	-0.109	-0.132	-0.12	-0.109	-0.12	-0.109	1	-0.103
P10	-0.068	-0.068	-0.068	-0.023	-0.068	-0.068	-0.068	-0.068	-0.068	1

Table.11: $(I-N)^{-1}$:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	1.1889	0.1411	0.1133	0.1323	0.1	0.1113	0.0866	0.0996	0.1197	0.0692
P2	0.1075	1.1906	0.1013	0.1434	0.0971	0.121	0.1022	0.1205	0.1311	0.0823
P3	0.1057	0.136	1.1722	0.1547	0.1169	0.1293	0.1048	0.1106	0.1342	0.0828
P4	0.1327	0.1539	0.1403	1.1893	0.1203	0.1271	0.13	0.1184	0.1531	0.0863
P5	0.1099	0.1262	0.1331	0.1425	1.1733	0.1417	0.1162	0.1095	0.1538	0.0859
P6	0.0961	0.1271	0.1294	0.1347	0.1442	1.1846	0.1236	0.1316	0.155	0.0894
P7	0.1007	0.1147	0.0987	0.1345	0.1098	0.124	1.1733	0.1316	0.136	0.0864
P8	0.1031	0.1215	0.109	0.1111	0.1144	0.124	0.1321	1.1733	0.1353	0.0886
P9	0.1349	0.1305	0.1328	0.1471	0.1357	0.1323	0.1361	0.1353	1.1722	0.1094
P10	0.082	0.0811	0.0818	0.0278	0.0813	0.082	0.0817	0.0823	0.1021	1.0602

Table.12: Total Relationship Matrix T or $N \times (I-N)^{-1}$:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	0.11	0.29	0.18	0.25	0.17	0.21	0.16	0.21	0.26	0.12
P2	0.19	0.12	0.16	0.27	0.2	0.25	0.21	0.28	0.26	0.14
P3	0.17	0.21	0.12	0.3	0.24	0.27	0.18	0.21	0.24	0.13
P4	0.21	0.28	0.25	0.13	0.21	0.25	0.25	0.22	0.29	0.12
P5	0.18	0.21	0.22	0.23	0.11	0.28	0.19	0.21	0.29	0.13
P6	0.17	0.25	0.23	0.23	0.26	0.13	0.22	0.25	0.3	0.15
P7	0.19	0.21	0.18	0.27	0.18	0.2	0.13	0.27	0.28	0.14

P8	0.2	0.27	0.18	0.21	0.18	0.21	0.24	0.13	0.27	0.15
P9	0.27	0.27	0.26	0.3	0.27	0.26	0.28	0.26	0.13	0.22
P10	0.13	0.14	0.13	0.1	0.13	0.13	0.13	0.14	0.15	0.07

Table.13: The Final Output:

Factor	Ri	Ci	Ri+Ci	Ri-Ci
1. Unsuitable Vehicle Selection	1.99	2.05	4.04	-0.06
2. High Transportation Cost	2.14	2.38	4.52	-0.24
3. Road Permeability	2.08	2.12	4.2	-0.04
4. Transportation Capacity	2.25	2.16	4.41	0.09
5. Road Condition	2.18	2.18	4.36	0
6. Traffic Jam	2.25	2.2	4.45	0.05
7. Unbalanced Supply Demand	2.22	2.11	4.33	0.11
8. Fuel Cost Fluctuations	2.19	2.19	4.38	0
9. Delay in Delivery	2.56	2.4	4.96	0.16
10. Security Risk	1.3	1.33	2.63	-0.03

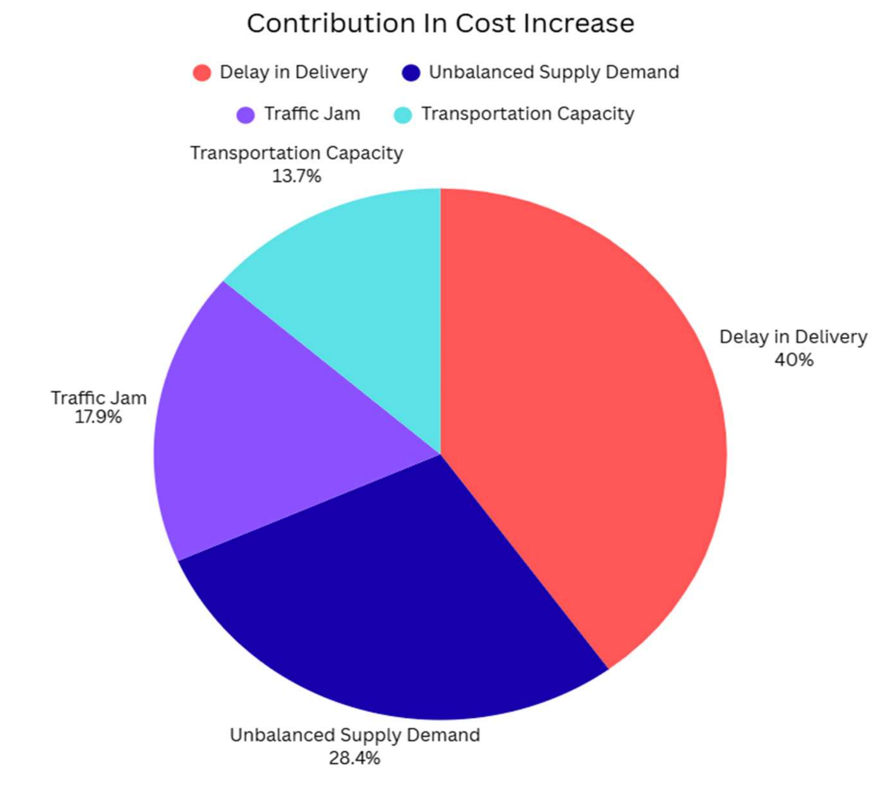

Fig.4: Factors Contribution in Cost Increase

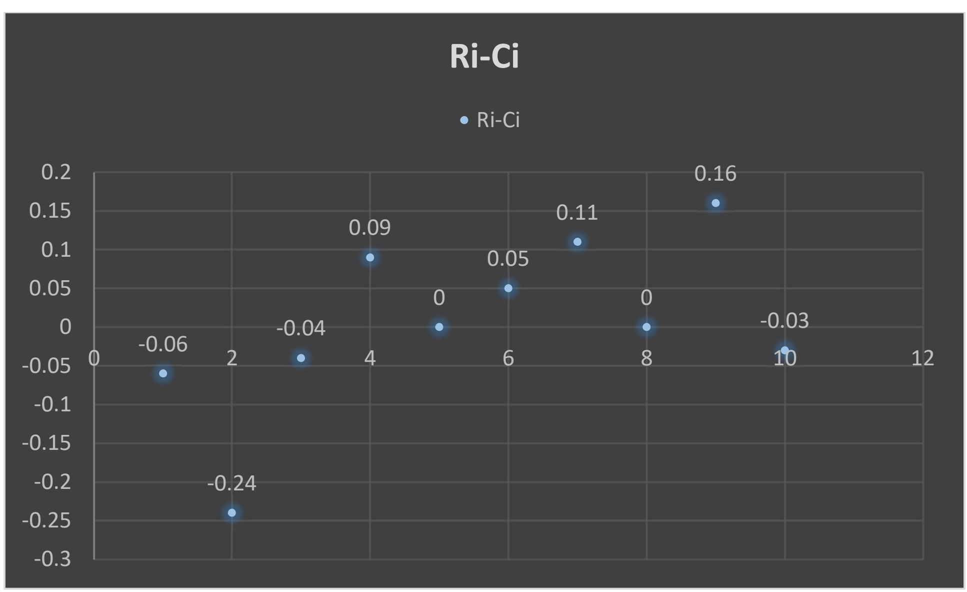

Fig.5: Cause-Effect Diagram

Cause Factors (Influencers): Factors with positive Ri-Ci values:

4. Transportation Capacity *(0.09)*

6. Traffic Jam *(0.05)*

7. Unbalanced Supply Demand *(0.11)*

9. Delay in Delivery *(0.16)*

Effect Factors (Receivers): Factors with negative Ri-Ci values:

1. Unsuitable Vehicle *(-0.06)*

2. High Transportation Cost *(-0.24)*

3. Road Permeability *(-0.04)*

10. Security Risk *(-0.03)*

Zero Values (Ri-Ci = 0):

5. Road Condition (0.00)

8. Fuel Cost Fluctuations (0.00)

These have equal influence and dependence

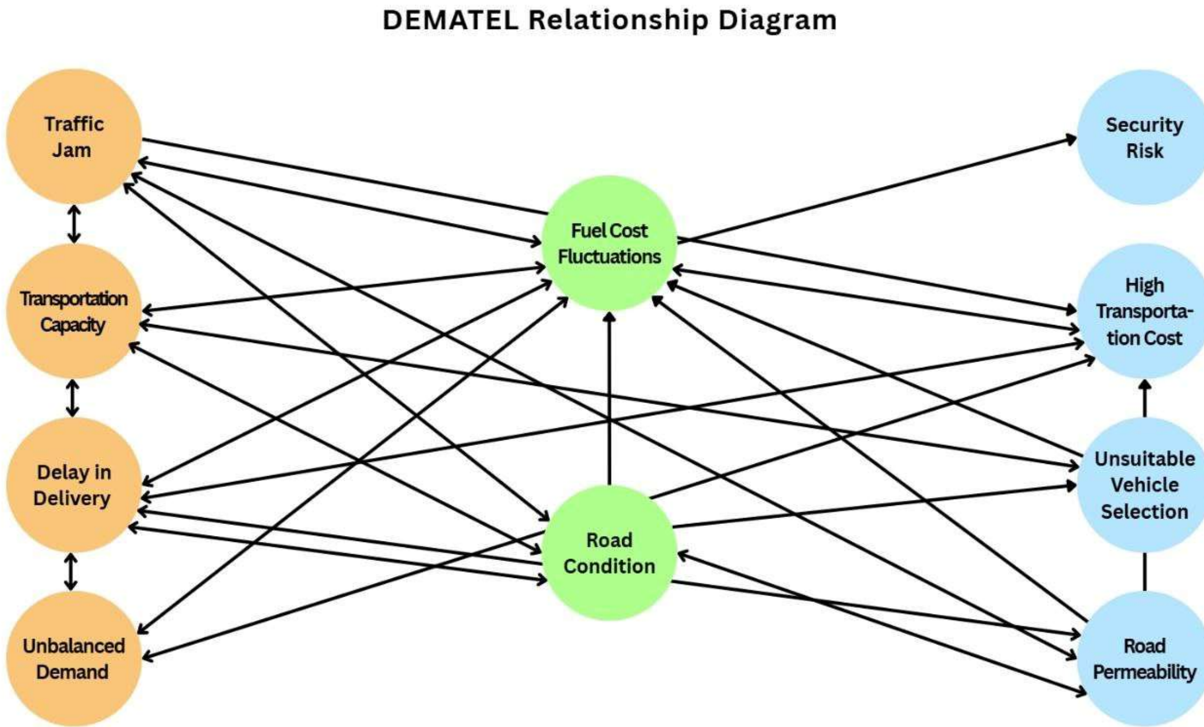

Fig.6: Cost Impact Channel between Cause & Effect

5. Result: After applying the three transportation algorithms, the results show that the Vogel Approximation Method (VAM) yields a cost saving of 12.25% compared to the North-West Corner Method and 10.74% compared to the Least-Cost Method for a single production season. As the VAM solution was already optimal, there was no need to apply the UV or MODI methods for further refinement; it represents the ultimate optimized route for these specific circumstances.

According to the DEMATEL analysis, the major cause factors in this transportation scenario are Delay in Delivery and Unbalanced Supply-Demand, which were found to have the highest influence scores among the cause group. These factors directly lead to higher transportation costs, which was identified as the most significant effect. The analysis also revealed two factors with a net value of zero, indicating they have equal influence and dependence within the system.

A set of potential solutions has been proposed to address these major cause problems.

Table.15: Possible Solutions for Cause:

Cause Factor (from DEMATEL)	Possible Solutions

Transportation Capacity (P4)	Fleet expansion, long-term contracts with logistics providers, multimodal transport (rail/river)
Traffic Jam (P6)	Route optimization software, night-shift trucking, govt. coordination on port access
Unbalanced Supply–Demand (P7)	Demand forecasting, flexible contracts with 3PLs, dynamic allocation system
Delay in Delivery (P9)	Buffer stock strategy, digital tracking (IoT), supplier diversification

6. Conclusion: In this paper, we tackled the real-world transportation challenges faced by a steel manufacturing company in Bangladesh. We used a two-part approach: first, we found the cheapest way to move materials using classic transportation methods, and then we dug deeper to understand why problems keep happening using a MCDM technique called DEMATEL.

We found that the Vogel's Approximation Method (VAM) gave us the best possible price for this specific situation, beating the other methods. But the real insight came from the DEMATEL analysis. It showed us that issues like delivery delays and mismatches between supply and demand are not just isolated problems, they are the root causes that trigger other issues, like high costs, which is actually a cause of long term failures.

For an industry, this is not just finding a cheaper route on a map. It is about fixing these core problems first. By focusing on the causes we identified, they can make quick and meaningful improvements.

At last we can say that, this work could be expanded by creating a smart system that adjusts routes in real-time for traffic, or by testing this same method in other industries like textiles, agriculture and logistic sector.

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