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Optimizing Financial Loan Processing Through Transportation In Networks

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Abstract: This paper presents a novel application of transportation problems and network flow optimization to improve loan processing efficiency in the banking industry. We model the loan processing system as a network, where banks act as supply nodes, agencies as demand nodes, and loan processing paths as arcs. The transportation problem is formulated to minimize processing costs. Additionally, network flow optimization is applied to minimizing processing time. Our results demonstrate the effectiveness of these optimization techniques in enhancing the efficiency of loan processing networks. The proposed approach can be applied to various industries with complex processing networks, leading to improved productivity and competitiveness.

Index terms - Transportation problem, network flow, optimization, banking industry, process improvement.

1. Introduction: -

In today's fast-paced financial landscape, efficient loan processing is crucial for financial institutions to remain competitive. However, complex networks and high volumes of loan applications can lead to bottlenecks, delays, and increased costs. Loan recovery is a critical concern for banks, with outstanding loans impacting financial performance and stability. Effective recovery strategies are essential to minimize losses. This paper addresses the challenge of optimizing loan recovery costs and timelines for three banks with outstanding loans, utilizing the services of three collection agencies. We employ a two-stage approach: First stage: Transportation Problem Modeling formulates the loan recovery process as a transportation problem, aiming to minimize the cost of recovering each unit of the loan amount. This stage determines the optimal allocation of loans to collection agencies. The second stage: Network Modeling represents the loan recovery process as a network model, where the three banks and three collection agencies form nodes. We seek the shortest path to recover loans, minimizing the time taken. By integrating these two approaches, we provide a comprehensive framework for optimizing loan recovery, considering both cost and time efficiency. In this paper separate network diagrams are given. Each diagram will have its own nodes and edges. Once the solution for each route is formulated, it is compared to determining the best overall route that minimizes time.

2. Literature review: -

The transportation problem, a cornerstone of operations research, has been extensively explored through various methods and applications over the decades. The classical models and methodologies developed by early pioneers continue to influence modern advancements.

The seminal works of Dantzig (1951) [7] and Ford and Fulkerson (1956) [10] laid the groundwork for solving transportation problems using the simplex and network flow methods. Dantzig introduced the application of the simplex method to transportation problems, emphasizing the efficiency of linear programming in optimizing resource allocation. Ford and Fulkerson expanded this foundation with their work on solving the transportation problem, providing insights into network flow dynamics. Charnes and Cooper (1954) [5] contributed the stepping stone method, a practical approach for interpreting linear programming solutions in transportation problems. This methodology remains a fundamental teaching tool for illustrating optimization techniques. Dijkstra's (1959) [8] algorithm for finding the shortest path in a graph introduced a deterministic approach that is widely used in transportation and logistics applications. Similarly, Kruskal (1956) [13] addressed graph optimization problems, particularly the shortest spanning tree, which holds relevance in designing efficient transportation networks.

Cunningham's (1976) [6] network simplex method represents a significant advancement, offering computational efficiency for solving minimum cost flow problems in large-scale networks. Eroglu (2013) [9] further refined the application of the network simplex method, demonstrating its practical utility in optimizing transportation costs. Carlier's dual contributions in 2003 [3][4] tackled multidimensional optimal transportation problems and explored duality principles, extending the applicability of transportation models to complex economic systems. These studies provided valuable theoretical frameworks for addressing real-world challenges. Ahmed and Sultana (2017) [16] proposed an innovative approach to finding an initial basic feasible solution for transportation problems, simplifying the process of obtaining optimal solutions. Similarly, Raigar and Modi (2017) [18] developed effective methodologies to streamline transportation problem-solving processes.

The integration of uncertainty into transportation network design has gained traction in recent years. Ait Mamoun and Hammadi (2022) [12] explored optimization models for transportation networks under uncertainty, emphasizing the importance of adaptability in dynamic environments. Wang, Crainic, and Wallace (2016) [20] examined stochastic scheduled service network design, highlighting the value of deterministic solutions in addressing uncertain conditions. Kadhim (2015) [11] introduced a novel algorithm for solving transportation problems with network-connected sources, addressing the unique challenges of interconnected supply chains. Abdelati (2023) [15] conducted a comparative study of multi-objective solid transportation problems, offering alternative decision-making strategies for complex scenarios.

The intersection of transportation optimization and supply chain finance has garnered significant attention. The Asian Development Bank (2022) [2] emphasized the role of supply chain finance programs in enhancing trade efficiency. Similarly, research on supply chain financial systems by Operation Optimization of Supply Chain Financial System (2022) [17] utilized system dynamics to optimize financial operations, ensuring robust logistics and supply chain performance. Spivey and Powell (2004) [14] addressed the dynamic assignment problem, offering insights into real-time decision-making processes in supply chain management. VUZF Review (2021) [19] discussed the optimization of financial incentives for logistics activities, focusing on the construction industry.

Foundational and contemporary studies collectively underscore the evolution of transportation problem-solving techniques. Ahuja, Magnanti, and Orlin's (1993) [1] comprehensive text on network flows synthesizes theory, algorithms, and applications, serving as an invaluable resource for practitioners and researchers alike. These advancements not only enhance the efficiency of transportation systems but also bridge the gap between theoretical models and practical applications, enabling effective decision-making in diverse industries. This growing body of knowledge highlights the ongoing importance of transportation problem research in addressing global logistical challenges.

3. Preliminaries: -

Definition 3.1: A linear programming problem that deals with the optimal distribution of goods or products from multiple sources (origins) to multiple destinations is called the transportation problem.

Definition 3.2: The amount of goods or products available at each origin is called supply and the amount of goods or products required at each destination is called demand.

Definition 3.3: The cost of moving a unit of goods or products from an origin to a destination is called the transportation cost and a graph representing the possible routes between origins and destinations is called the transportation network.

Definition 3.4: A solution that minimizes the total transportation cost while satisfying all supply and demand constraints is called the optimal solution.

Definition 3.5: A directed graph representing the network, where each edge has a capacity, and each node has a supply or demand is called a flow network.

Definition 3.6: The maximum amount of flow that can be sent from the source to the sink while satisfying all constraints is called the maximum flow.

4. Transportation problem by stepping stone method: -

Step 1: Formulate the problem mathematically:

Minimize: $\sum_i \sum_j c_{ij}\, x_{ij}$ (Total Transportation Cost)

Subject to:

$\sum_i x_{ij}$ = ai (Supply constraint for each source i)

$\sum_i x_{ij}$ = bj (Demand constraint for each destination j)

$x_{ij} \geq 0$ (non-negativity constraint)

Step 2: Initialize the transportation problem:

Components	D_1	D_2	$D_3\ldots$	D_j	SUPPLY
S_1	c_{11}	c_{12}	$c_{13}\ldots$	c_{1j}	a_1
S_2	c_{21}	c_{22}	$c_{23}\ldots$	c_{2j}	a_2
….	…	…	…	…	…
S_k	c_{k1}	c_{k2}	$c_{k3}\ldots$	c_{kj}	a_k
DEMAND	b_1	b_2	$b_3\ldots$	b_j	

Table 4.1 General Transportation Table

Step 3: Find the starting basic feasible solution

Assign x_{ij} = min(a_i, b_j) to the cell with the minimum cost (c_{ij}) in each row and column.

Step 4: Identify the most negative opportunity cost (Δ_{ij}) by calculating:

$\Delta_{ij} = c_{ij} - u_i - v_j$, where u_i and v_j are the dual variables for row i and column j, respectively.

Select the cell with the most negative Δ_{ij} and add 1 to x_{ij}. Update the supply and demand constraints accordingly.

Step 5: Repeat Step 4 until optimality until it attains $\Delta_{ij} \geq 0$

Step 6: The optimal solution is the final values of x_{ij}, which represent the amount transported from each source to each destination is calculated.

5. Network Flow Model Algorithm: -

Step 1: Estimate activity times by calculating the maximum flow in the network, where each activity's duration is represented by the capacity of its corresponding arc.

Step 2: Calculate Earliest Start Time (EST) and Earliest Finish Time (EFT) for each activity where

EST = Measure of all predecessor activities

EFT = EST + Activity Duration

Calculate Latest Start Time (LST) and Latest Finish Time (LFT) for each activity where

LFT = Measure of all successor activities - Activity Duration

LST = LFT - Activity Duration

Step 3: Calculate the critical path that represents the amount of time an activity can be delayed without impacting the project deadline.

Step 4: Calculating the total time needed to complete the process for each path

Path Duration = $\Sigma T_1 + T_2 + T_3 + \ldots\ldots + T_5$

Step 5: Comparing the values and finding the shortest route by calculating the total duration for each path and comparing them to find the shortest route.

6. Numerical Example: -

Three banks (S_1, S_2, S_3) have outstanding loans that are past due and need to be recovered. They have hired three collection agencies (D_1, D_2, D_3) to help recover the loans. The costs of recovering one unit of the loan amount from each bank to each collection agency are given in the table below. The optimal loan recovery plan minimizes the total recovery cost and minimizes the time taken by each bank to recover loans.

The goal is to find the optimal amount of loans to assign to each collection agency from each bank to minimize the total recovery cost.

6.1 Solving the transportation problem by stepping stone method:

Step 1 and Step 2 :

COMPONENTS	D_1	D_2	D_3	SUPPLY
S_1	2	3	1	30
S_2	5	4	8	50
S_3	5	6	8	20
DEMAND	20	40	40	100

Table 6.1.1 Transportation Table

The sources (S_1, S_2, S_3) are the three banks with outstanding loans, and the destinations (D_1, D_2, D_3) are the three collection agencies. The costs in the table represent the costs of recovering the loans (e.g., commission fees) for each bank-agency pair.

Total number of supply constraints : 3
Total number of demand constraints : 3

Number of rows = Number of columns

The given problem is a balanced one.

Step 3: Initial feasible solution is

COMPONENTS	D_1	D_2	D_3	SUPPLY
S_1	2 (20)	3 (10)	1	30
S_2	5	4 (30)	8 (20)	50
S_3	5	6	8 (20)	20
DEMAND	20	40	40	

Table 6.1.2 Feasible Solution

The minimum total transportation cost $=2\times20+3\times10+4\times30+8\times20+8\times20=510$
Here, the number of allocated cells is 5 and the solution is non-degenerate.

Step 4: Finding the optimal solution by stepping stone method

The transportation costs of each cell traced in the closed path are added. This process is iterated for all the unoccupied cells.

UNOCCUPIED CELLS	CLOSED PATH	NET COST CHANGE
S_1D_1	$S_1D_1 \rightarrow S_1D_3 \rightarrow S_3D_3 \rightarrow S_3D_1$	2 - 1 + 8 - 5=4
S_1D_2	$S_1D_2 \rightarrow S_1D_3 \rightarrow S_3D_3 \rightarrow S_3D_1 \rightarrow S_2D_1 \rightarrow S_2D_2$	3 - 1 + 8 - 5 + 5 - 4=6
S_2D_3	$S_2D_3 \rightarrow S_2D_1 \rightarrow S_3D_1 \rightarrow S_3D_3$	8 - 5 + 5 - 8=0
S_3D_2	$S_3D_2 \rightarrow S_3D_1 \rightarrow S_2D_1 \rightarrow S_2D_2$	6 - 5 + 5 - 4=2

Table 6.1.3 Path

Step 5: All net cost change ≥ 0 (Non-negative). We stop the process and thus the final optimal solution has arrived.

COMPONENTS	D_1	D_2	D_3	SUPPLY
S_1	2	3	1 (30)	30
S_2	5 (10)	4 (40)	8	50
S_3	5 (10)	6	8 (10)	20
DEMAND	20	40	40	

Table 6.1.4 Optimal Solution

Step 6: The optimal solution for the transportation problem.

The minimum total transportation cost =1×30+5×10+4×40+5×10+8×10=370.

Calculating percentage reduction in cost				
Transportation	Cost		Difference	Percentage Reduction
	Original Cost	Optimal Cost		
Cost	510	370	140	27.4%

Table 6.1.5 Percentages reduction in cost

6.2 Constructing a network model with the transportation problem to minimize the time by finding the shortest distance: -

Let's start with the first diagram: S_1 to D_1.

The diagram with nodes and edges are given below

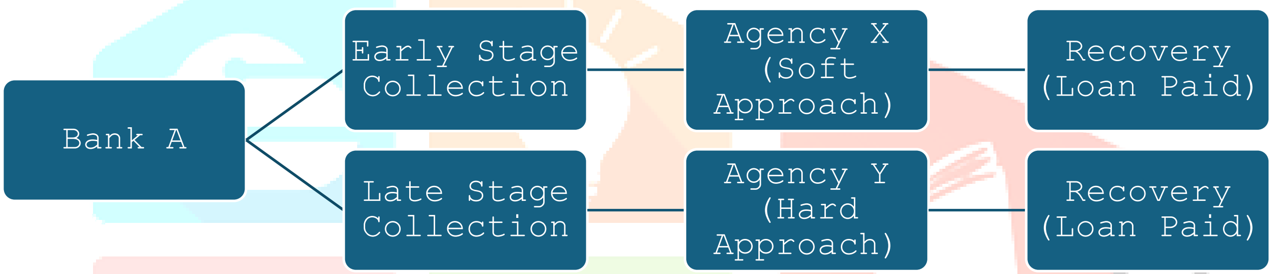

Fig 6.2.1 Constructing a network model with the transportation problem

Step 1: Estimate activity times

1. Bank A → Early Stage Collection: 1 day

2. Bank A → Late Stage Collection: 3 days

3. Early Stage Collection → Agency X: 2 days

4. Late Stage Collection → Agency Y: 4 days

5. Agency X → Recovered Loans: 5 days

6. Agency Y → Recovered Loans: 7 days

Step 2: EST, EFT, LST and LFT and the slack times.

STAGES	DURATION	EST	EFT	LFT	LST	SLACK
Bank A → Early Stage Collection:	1	0	1	6	5	5
Bank A → Late Stage Collection:	3	0	3	3	0	0
Early Stage Collection → Agency X:	2	1	3	9	7	6
Late Stage Collection → Agency Y:	4	3	7	7	3	0
Agency X → Recovered Loans:	5	3	8	14	9	6
Agency Y → Recovered Loans:	7	7	14	14	7	0

Table 6.2.1 EST, EFT, LST and LFT and the slack times.

Step 3:

The critical path is: Bank A → Late Stage Collection → Agency Y → Recovered Loans

Step 4: The process for each path:

BANK	STAGES	AGENCY		Total days	
A	Early Stage Collection	Agency X	Recovered Loans	1 + 2 + 5	8 days
		Agency Y		1 + 2 + 7	10 days
	Late Stage Collection	Agency X		3 + 4 + 5	12 days
		Agency Y		3 + 4 + 7	14 days

Table 6.2.2 Process for each path

Step 5: Comparing the values from S_1 to D_1.

- The fastest path is Bank A → Early Stage Collection → Agency X → Recovered Loans, taking only 8 days.

Similarly consider for S_2 to D_2 and S_3 to D_3.

Hence, by following the optimal paths identified in each bank's process, the time taken to complete the process is minimized.

Calculating percentage reduction in time				
Bank	Processing Time (Days)		Difference	Percentage Reduction
	Minimum	Maximum		
A	8	14	6	42.86%
B	14	20	6	30%
C	18	25	7	28%

Table 6.2.3 Percentages reduction in time

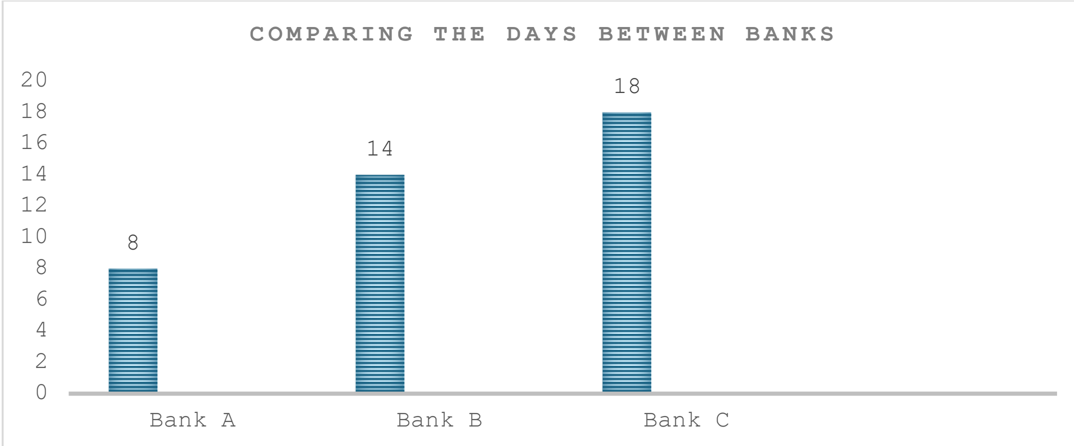

Fig 6.2.2 Comparing the Days Between Banks

7. Conclusion: -

The transportation problem solution reveals the optimal allocation of loan recovery tasks from three banks (S_1, S_2, S_3) to three collection agencies (D_1, D_2, D_3) that minimizes the total cost. The results show that the optimal allocation achieves a minimum total cost of 370. From the Transportation problem and the network diagram we have minimized the cost and the time respectively. The results are consistent across methods Network Flow Optimization, Ford-Fulkerson Method, Edmonds-Karp Algorithm, Dinic's Algorithm. This solution enables the banks to efficiently outsource their loan recovery tasks to the agencies, reducing their overall costs and improving their financial performance. By minimizing the time, the banks can reduce processing costs, enhance customer satisfaction, gain a competitive edge in the market. By implementing this optimal allocation, the banks and agencies can streamline their loan recovery process, leading to cost savings and improved productivity.

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