LEXICOGRAPHIC APPROACH
FOR QUADRATIC TRANSPORTATION PROBLEM
WITH ADDITIONAL RESTRICTION

A
SYNOPSIS

SUBMITTED IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY
IN
COMPUTER SCIENCE

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UNDER THE SUPERVISION OF
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DAYALBAGH, AGRA
MARCH 2015
INTRODUCTION

Mathematical optimization is an interdisciplinary subject that deals with choosing the best among a given set of finite or infinite alternatives. The optimization problems can be classified as given in table 1.

Table 1: Classification of optimization problems

<table>
<thead>
<tr>
<th>Classification based on</th>
<th>Sub-classification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of constraints</td>
<td>Constrained optimization problems</td>
<td>A problem with one or more constraints</td>
</tr>
<tr>
<td></td>
<td>Un-constrained optimization problem</td>
<td>No constraints exists</td>
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<td>Nature of decision variable</td>
<td></td>
<td></td>
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<tr>
<td>Physical structure</td>
<td>Optimal control</td>
<td>A mathematical problem involving a number of stages, each stage evolving from the preceding stage</td>
</tr>
<tr>
<td></td>
<td>Non-optimal control</td>
<td>Which are not optimal control</td>
</tr>
<tr>
<td>Nature of equations involved</td>
<td>Linear</td>
<td>Which are linear in nature</td>
</tr>
<tr>
<td></td>
<td>Non-Linear</td>
<td>objective function and constraints are not linear</td>
</tr>
</tbody>
</table>

Quadratic Programming Problem

An optimization problem with a quadratic objective function and linear constraints is called a quadratic programming problem (Sahni, 1974). Study of quadratic programming is important because it forms the basis of several general nonlinear programming algorithms. The real-life problems that include quadratic functions are portfolio optimization (financial applications), power generation optimization (electrical applications), and design optimization (engineering applications).

Mathematically the general quadratic program is as follows

\[
\begin{align*}
\text{min } Q(x) &= cx + \frac{1}{2}x^TDx \\
\text{s.t } Ax &\leq b \\
\text{and } x &\geq 0
\end{align*}
\]

(1)

(2)

(3)

Here \(c\): n-dimensional row vector of coefficients of the linear objective function

\(D\): \((n \times n)\) symmetric matrix of the coefficients of the quadratic terms.

\(x\): n-dimensional column vector of the decision variables
\( \mathbf{x}^T \): Transpose of \( \mathbf{x} \)

\( \mathbf{A} \): \((m \times n)\) matrix of constraints

\( \mathbf{b} \): \(m\)-dimensional column vector of right-hand-side coefficients.

A sufficient condition to guarantee strictly convexity is for \( \mathbf{D} \) to be positive definite.

**Transportation Programming Problem**

The conventional transportation problem (Hitchcock, 1941) is a well-structured problem that deals with the distribution of goods from \( m \) suppliers (also known as sources) to \( n \) customers (also known as destinations). Each of these suppliers can ship to any of the customers (or purchaser) at a shipping cost per unit cost \( c_{ij} \) (i.e. from supplier \( i \) to customer \( j \)). Each supplier has \( s_i \) units of capacity and each purchaser has a requirement of \( d_j \) units. The objective is to schedule shipments from sources to destinations such that the total transportation cost, \( \sum \sum c_{ij}x_{ij} \), is minimized.

Mathematically a transportation problem is formulated as follows:

\[
\text{minimize} \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \quad \text{(4)}
\]

s.t

\[
\sum_{j=1}^{n} x_{ij} = s_i \quad i=1,2,...,m \quad \text{(5)}
\]

\[
\sum_{i=1}^{m} x_{ij} = d_j \quad j=1,2,...,n \quad \text{(6)}
\]

\[x_{ij} \geq 0 \quad \text{for all } (i, j) \quad \text{(7)}
\]

A necessary and sufficient condition for obtaining the solution of a transportation problem is

\[
\sum_{i=1}^{m} s_i = \sum_{j=1}^{n} d_j \quad \text{(8)}
\]

i.e. total supply = total demand
Quadratic Transportation Problem

The quadratic transportation problem (QTP) (Megiddo & Tamiry, 1993; Cosares & Hochbaum, 1994) is stated as a distribution problem where each of the m suppliers can ship units to any of the n customers at cost \( f_{ij}(x_{ij}) \) and where \( f_{ij} \) is a quadratic function of \( x_{ij} \) the amount shipped from source i to destination j. The objective is to minimize the total transportation cost while meeting demand at the destinations.

Mathematically, a QTP is formulated as:

\[
\min Z = \sum_{i=1}^{m} \sum_{j=1}^{n} f_{ij}(x_{ij}) \tag{9}
\]

s.t. \( (5), (6) \) and \( (7) \)

\[
f_{ij}(x_{ij}) \geq 0
\]

\[
f_{ij}(0) = 0
\]

Other optimization problems useful for real-life applications are:

**Fractional Programming**

A set of problems where a function, characterized by ratios of given functions, with the objective of optimizing (maximizing or minimizing) is commonly called Fractional Programming Problems. Ratios studied in real life problem are debt/equity, output/employee, profit/cost, inventory/sales, risk-assets/capital or other quantities to be optimized.

Mathematically a Fractional Program is of the form:

\[
\max \ (\min) \ p(x) = \frac{f(x)}{g(x)} \tag{10}
\]

subject to

\[
h_i(x) \leq b_i \quad (i = 1,2,\ldots,m) \tag{11}
\]

\[
x \geq 0 \tag{12}
\]

Here \( x \in \mathbb{R}^n \), \( f(x) \), \( g(x) \) and \( h_i(x) \) are real valued scalar functions defined on a subset of \( \mathbb{R}^n \). The above definition holds if \( g(x) > 0 \) for all \( x \) on \( X \). For \( g(x) < 0 \), the expression given below may be used

\[
q(x) = \frac{-f(x)}{-g(x)} \tag{13}
\]
Fractional transportation problems arise in many real life situations where the enterprise board is confronted with optimization of fractional transportation costs acquired from sources $i$ to destinations $j$ (Sharma, 1973; Gupta, 1977 and Sharma, 1978).

Mathematically a fractional transportation problem may be of the form:

$$
\text{min } z = \frac{\sum_{i} \sum_{j} c_{ij} x_{ij}}{\sum_{i} \sum_{j} d_{ij} x_{ij}}
$$

subject to

(5), (6) and (7)

**Multi-Objective Fractional Program**

A special class of LP where the objectives are conflicting in nature is referred to as a multi-objective problem. The proposed methods to solve these problems generate a set of non-dominated or compromise solution.

Mathematically multi-objective fractional problem are given as:

$$
\text{max} \left[ q_1(x), q_2(x), \ldots, q_p(x) \right] \text{ subject to } h_i(x) \leq b_i, x \geq 0
$$

where

$$
q_i(x) = \frac{c_i^T x + \alpha_i}{d_i^T x + \beta_i}
$$

(16)

$$
q_2(x) = \frac{c_2^T x + \alpha_2}{d_2^T x + \beta_2}
$$

(17)

$$
\vdots
$$

$$
q_p(x) = \frac{c_p^T x + \alpha_p}{d_p^T x + \beta_p}
$$

(18)

In a multi-objective transportation problem (Isermann, 1979) a product is to be transported from $m$ sources to $n$ destination and with capacities $s_i$ and requirements $d_j$ ($i = 1, 2, \ldots, m; j = 1, 2, \ldots, n$). Transportation cost $c_{ij}$ is associated with transporting a unit of product from $i^{th}$ source to $j^{th}$ destination and variable $x_{ij}$ is the unknown quantity to be allocated for shipping from $i^{th}$ source to $j^{th}$ destination.

Mathematically multi-objective transportation problem with $r$ objectives, $m$ source and $n$ destinations can be written as
\[
\text{minimize } Z_r = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}^r x_{ij} \quad r = 1, 2, \ldots, k \quad (19)
\]

subject to (5), (6) and (7).

The subscript \( r \) of \( Z \) and cost are related to the \( r^{th} \) penalty criterion.

Challenge before the transportation system analyst is to abstract from the complexity of reality a simplified model which can be manipulated to access the various options to him for decision making in the real life situation.

**Decision support system**

A Decision Support System (DSS) is an interactive system which utilizes analytical models and decision rules coupled with database and the insight of the decision maker. Instead of replacing the decision making capability of a human being, a DSS couples the intellectual resource of individuals with the capabilities of improving the quality of decisions. The DSSs are indispensable in situations when precision and optimal decision making is important. It provides intelligent access to relevant knowledge and aids the process of structuring decision.

**Characteristics of DSS**

1. Interactive, flexible and adaptable
2. Handles large amounts of data
3. Helps in performing complex, sophisticated analysis and comparisons
4. Supports optimization and heuristic approaches
5. Performs *what-if* and goal-seeking analysis

In the real world, a variety of transportation problems arise depending on the conditions. The behaviour of objective function and the constraints vary with the transportation problems. There is no general model of transportation problems, which can be applicable to all the variety of transportation problems. Thus there is a need to develop new models of transportation problems for decision making. The proposed study is an attempt in this direction.
Literature review

Researches are continuously making efforts to formulate new optimization problems and find the solution procedure for these.

Quadratic Transportation Problem

Kaltinska (1994) studied the features of quadratic transportation problems where the objective function was a product of two affine functions. Algorithms were also designed to solve such problems. A three-dimensional fixed charge bi-criterion indefinite quadratic transportation model was developed by Arora and Khurana (2004) to find the efficient cost time trade off of pair. Cattiaux and Guillin (2006) introduced new families of inequalities (for quadratic transportation cost and for relative entropy) that are shown to be equivalent to the Poincaré inequality. Khurana and Arora (2011) studied a fixed charge bi-criterion quadratic transportation problem with enhanced flow and presented an algorithm to find an efficient cost-time trade off pairs in for the problem.

A direct analytical algorithm was applied to solve transportation problems with quadratic function cost coefficients Adlakha & Kowalski (2013) using the concept of absolute points. Gupta & Arora (2013) proposed an indefinite quadratic transportation problem with the flow constraint. This constraint was replaced by two additional destinations a) for supplementing the total flow up to a specific level, and b) for identifying the supply points preferred to keep reserves. Jalilzadeh & Hamedani (2014) presented the combination aspect of the quadratic transportation problem and obtained an inverse form of quadratic transportation problem by using duality approach.

Transportation Problems

Different transportation models have been applied to a broad class of decision problems.

a. Fractional transportation problems

Dahiya & Verma (2006) discussed a paradox in fixed charge capacitated transportation problem. The objective function considered was the sum of two linear fractional functions consisting of variables costs and fixed charges respectively. A paradox arises when the transportation problem admits of an objective function value which is lower than the optimal objective function value, by transporting larger quantities of goods over the same route. Moanta (2007) presented a three-dimensional transportation problem in which the objective function is the ratio of two positive linear functions. A Transportation problem with fractional objective function was investigated by Joshi & Gupta (2011) when the demand and supply quantities are varying. The total cost bounds were calculated directly. Sivri, Emiroglu, Güzel, & Tasci (2011) dealt with the transportation problem of minimizing the ratio of two linear functions subject to constraints of the conventional transportation problem. A new algorithm in order to obtain an initial solution was also proposed for the problem which is similar to Vogel approximation method. Charles, Yadavalli, Rao, & Reddy (2011) proposed a stochastic programming model, while considering ratio of two non-linear functions and probabilistic constraints.
A decomposition approach to solve a fuzzy transportation problem with linear fractional fuzzy objective function was proposed by Narayananamoorthy & Kalyani (2015) where the fractional fuzzy transportation problem was decomposed into two linear fuzzy transportation problems. Güzel, Emiroglu, Tapci, Guler & Syvry (2012) transformed a fractional transportation problem with interval coefficient to a classical transportation problem by expanding the order 1st Taylor polynomial series with multi variables.

The data of real world applications generally cannot be expressed strictly. An efficient way of handling this situation was presented by Dalman, Köçken & Sivri (2013) in the Indefinite Quadratic Interval Transportation Problem where all the parameters i.e. cost and risk coefficients of the objective function, supply and demand quantities were expressed as intervals. A Taylor series approach was used for the solution of this problem. Gupta & Arora (2013) developed a transportation problem with an objective function as the sum of a linear and fractional function. The linear function represents the total transportation cost incurred in shipping goods from various sources to the destinations and the fractional function presents the ratio of sales tax to the total public expenditure. Ekezie, Ifeyinwa & Opara (2013) developed a transportation problem with an objective function as the sum of a linear and linear fractional function. A paradoxical situation arises in the sum of a linear and linear fractional transportation problem, when value of the objective function falls below the optimal value and this lower value is attainable by transporting larger number of passengers.

A solid transportation problem with interval cost was studied by Radhakrishnan & Anukokila (2014) using fractional goal programming approach. Special type of non-linear (hyperbolic) membership functions was used to solve multi-objective transportation problem.

An interactive fuzzy goal programming approach was proposed by Tkacenko (2014) to determine the preferred compromise solution for the multi-objective fractional transportation problem of bottleneck type. The proposed approach considers the imprecise nature of the input data by implementing the minimum operator.

b. Time transportation problem

The time transportation problem also known as the bottleneck transportation problem has been studied by various authors (Garfinkel & Rao, 1971; Sharma and Swarup, 1977; and Chandra, Seth and Saxena, 1987). Sharma and Swarup (1978) presented a transportation technique for time minimization in fractional functional programming problem. A non-convex optimization problem involving minimization of the sum of max and min concave functions over a transportation polytope was studied by Puri and Puri (2006). Sonia, Khandelwal, & Puri (2008) suggested to optimally partitioning the set of m sources for a given time minimizing transportation problem into two mutually disjoint subsets L1 and L2 where, L1 contains m1 sources called Level-I sources and L2 contains the remaining (m−m1) sources termed as Level-II sources. Nikolić (2007) studied a total transportation time problem considering the time of the active transportation routes. A polynomial time algorithm was proposed which minimizes the concave objective function. Chakraborty & Chakraborty (2010) proposed a method for the minimization of transportation cost as well as time of transportation. The problem was modelled as multi objective linear programming problem with imprecise parameters which was handled using Fuzzy parametric programming.
A transportation algorithm was applied by Uddin (2012) to determine the minimum transportation time which determined the initial basic feasible solution of transportation problem to minimize time. Singh (2012) first revealed the drawback in the approach suggested by Hammer (1969) for finding the optimal solution to a time minimization transportation problem for which the cost of transportation is minimal and also developed a procedure for providing the correct optimal solution. Quddoos, Javaid, Ali, & Khalid (2013) considered a bi-objective transportation problem, where the total transportation cost and delivery time was minimized. The lexicographic goal programming is used to solve this problem. Sharma, Malhotra, & Verma (2013) dealt with a trade-off between cost and pipeline at a given time in a transportation problem.

c. Transportation problem with additional constraint

In some practical applications, the product varies in some features according to its source. The final product mix, received at destinations, may then be required to meet known specifications. For example, crude ore contains different amounts of phosphorus impurity, according to its source and the actual time to process the ore depends on both its source and destination. This type of transportation problem is studied by Haley and Smith (1966), Chandra, Seth & Saxena (1987); Singh & Saxena (2003), and Pandian & Anuradha (2011).

d. Multi-objective transportation problem

Different algorithms have been developed to solve the Multi-objective transportation problem. Nunkaew & Phruksaphanrat (2009) proposed a multi-objective programming for depot to customer and customer to customer relationships. The objectives were to minimize the total transportation cost which is the baseline objective and to minimize the overall independence value. A Lexicographic Goal Programming (LGP) is applied to the proposed model. A multi-objective solid transportation problem was considered by Ojha, Das, Mondal & Maiti (2010) for a breakable item with two different criteria: cost and time for transportation. The breaking for the item depends on two modes- (i) type of conveyance and (ii) transported amount. The item breaks at constant rate for the modes of conveyance and randomly for the transported amount. The best solution out of this set was determined using Analytical Hierarchy Process. Zaki, Mousa, Geneedi & Elmekawy (2011) integrated both genetic algorithm (GA) and local search (LS) scheme an efficient genetic algorithm for solving multi-objective transportation problem, assignment, and transshipment problems. The algorithm maintains a finite-sized archive of non-dominated solutions which gets iteratively updated in the presence of new solutions based on clustering algorithm.

An approach based on the study of reducibility of the multi-index transport problems to that of seeking a flow on the network was proposed by Afraimovich (2012). A chance constrained multi-objective capacitated transportation problem was discussed by Pramanik & Banerjee (2012) based on fuzzy goal programming problem. The supply and demand constraints were converted into equivalent deterministic forms and the fuzzy goal levels of the objective functions were defined which were then characterized by the associated membership functions. Cetin & Tiryaki (2014) considered a multiobjective linear fractional transportation problem with several fractional criteria and provided a fuzzy approach to
obtain a compromise Pareto-optimal solution for this problem. The problem was reduced to the Zimmermann’s “min” operator model which is the max-min problem and Generalized Dinkelbach’s Algorithm is constructed for solving the obtained problem. A location–transportation problem with three-objectives was considered by Abounacer, Rekik & Renaud (2014) for disaster response. The proposed algorithm can be applied to any three-objective optimization problem provided that the problem involves at least two integer and conflicting objectives.

Maity & Roy (2014) studied multi-choice multi-objective transportation problem under the environment of utility function approach which was converted to multi-objective transportation problems by transforming the multi-choice parameters like cost, demand, and supply to real-valued parameters. Osuji, Okoli & Opara (2014) focused on the solution of multi-objective transportation problem using fuzzy programming algorithm. TORA, statistical software, was employed for the data analysis. Network models and integer programming are well known variety of decision making problems. Mubashiru (2014) applied Karush-Kuhn-Tucker (KKT) optimality algorithm to solve the problem of transportation with volume discount for a logistic operator in Ghana. Maity & Roy (2014) developed a mathematical model for a transportation problem consisting of a multi-objective environment with nonlinear cost and multi-choice demand. The focus of the paper was on objective functions of nonlinear type, which occur due to the extra cost of supplying goods remaining at their points of origin to various destinations, and on demand parameters that are considered to be of multi-choice type. Roy (2014) explored the study of multi-choice multi-objective transportation problem using utility function approach. The problem was converted to multi-objective transportation problems by transforming the multi-choice parameters like cost, demand, and supply to real-valued parameters. Kumar & Kaur (2014) presented single and multi-objective fuzzy multi-criteria fractional problems and proposed a new method for solving such type of decision problems.

Decision Support System

Researchers have developed decision support system for enhancing transportation system decision making process. Arampatzis, Kiranoudis, Scaloubacas, & Assimacopoulos (2004) designed a decision support system integrating it with a geographical information system to assist the transportation stakeholders enhance the transportation supply while improving two indicators: environmental and energy. An assessment framework was developed by Pekin et al. (2007) developed a decision support system to perform an ex-ante and ex-post potential policy measures to stimulate the use of intermodal transport in Belgium. Ülengina, Önsela, İkerTopçub, Aktaşb, & Kabak (2007) proposed a decision support system for transportation decision makers to design future strategic decisions and facilitate analysis of the consequences of changing the share of transportation modes for both passenger and freight transportation.

He and Zhang (2009) developed a decision support system based on multi-agent to raise the level of automation and intelligence for urban public transport management. Backeberg (2009) described the systems approach to implement a holistic transportation decision-support system, which will measure transportation performance at the highest level and enable improvements by effective decision-making in transportation system. Hasan (2010) proposed an intelligent decision support system that utilizes transportation network equilibrium modelling while providing an easy to use GIS-based interaction environment. Zografos, Mada & Saloura (2010)
described the decision-oriented modelling framework by developing a decision support system for airport operations management and planning and also demonstrated the decision support capabilities of the system. Matzoros (2010) implemented a decision support system for effective public transport management. Dias, Carvalho & Telhada (2011) proposed an integrated multi-disciplinary decision support system framework to support decision makers in designing flexible transportation systems. Yurshevich & Yatskiv (2011) presented a decision support system for managing urban transportation system and a possibility of using microscopic modelling as an integral part of the DSS when managing the urban transport system. Fanti, Iacobellis & Ukovich (2012) proposed the structure of a decision support system for monitoring hazardous materials vehicles, for solving two problems: i) assessing the risk induced on the population by such vehicles travelling in the motorways and ii) selecting the optimal routes and restoration procedures for the heavy vehicles. A decision support system was developed by Abduljabbar & Tahar (2012) by combining inventory and transportation operations in petroleum transportation system.

Chichernea & Dragos-Paul (2013) presented a Web-based DSS as a support to managers from the operational and real-time levels to plan transport of concrete and construction materials in an industrial construction area from a smart city. Casas, Torday, Perarnau, Breen & Villa (2013) presented a framework of decision support systems for traffic management based on short and medium-term predictions. Nowakowski & Werbińska-Wojciechowsk (2013) developed a decision support system for enhancing transport maintenance processes performance. Torretta, Raboni, Copelli & Urbini (2013) proposed a decision support system, called TrHaM (TRansport of Hazardous Materials) in order to both quantify the overall risk due to the transport of hazardous materials via road, railroad, waterway and pipeline. The algorithm evaluates and shows the risk distribution using stand-alone GIS software. Audy, D’Amours, Rousseau & Favreau (2013) presented a decision support system supporting collaborative transportation among freight transportation decision makers. The main components of the system as well as how transportation collaboration is organized with the system were detailed. Kepaptsoglou, Karlaftis & Bitsikas (2010) and Kontou, Kepaptsoglou, Charalampakis, & Karlaftis (2014) presented a decision support system for optimally allocating buses to bus-depots while minimizing deadhead costs. The authors also developed a method to keep the bus-depot occupant during ideal operational levels. An application of GIS based decision support system was presented by Akay & Kakol (2014) to determine the optimum route that minimizes the total cost of transporting forest products. ArcGIS was used for network analysis. Increase in mobility has coincided with a greater use of an individual mode of transport. This results in an inadequate organization of public transport services. In order to make more effective all initiatives to promote public transport, a large amount of information about service network accessible to users is essential. Vitale, Festa, Guido & Rogano (2014) presented a Decision Support System that relies on a logical network architecture characterized by the communication paradigm REST and powered by the use, on Client side, of smartphones that today have an enormous social relevance. Petroleum transportation has been paid more attention to, as the central logistics operation linking the upstream and downstream functions.
Motivation of proposed work

From the above discussion following are the main observations

- QPP has great importance from the mathematical and application viewpoint (Floudas and Visweswaran, 1995)
  
  The quadratic programming with linear constraints can be viewed as a generalization of the linear programming problem with a quadratic objective function. This means it ranges all linear programming problems, including applications in scheduling, planning and flow computation. Also, quadratic programming is known to be NP-hard, thus some interesting combinatorial optimization problems can be posed in a quadratic programming framework.
  
  There are several application areas that can be expressed as quadratic problems such as planning, scheduling, game theory, economics problem of scale, facility allocation-location, quadratic assignment problems, engineering design and problems in microeconomics.

- Quadratic functions are versatile. However, out of all nonlinear programming problems, quadratic functions and quadratic problems are the least difficult ones to handle (Dalman, Köcken & Sivri, 2013). However quadratic programming problem alone are not efficient to solve a distribution problem where m suppliers can ship units to n costumers.

- Quadratic transportation problem provides a superior representation of real life distribution (Adlakha & Kowalski, 2013)
  
  Sustainable prosperity in a city is possible only with affordable and accessible transport system. The primary objective of a comprehensive transportation system is to provide an optimum level of service within the capacity of its available fleet and crew, and the constraints of the total network and financial inputs.

  It was also observed that Quadratic transportation problems have not been much explored in literature therefore to fill this gap an effort will be made in this research work to formulate and solve this special class of optimization problem.
Proposed work

This research work is devoted to the study of quadratic transportation problems with additional restrictions and to develop procedure for solving this type of problems.

Objectives of the proposed study
1. To formulate quadratic transportation problem with 3 indices.
2. To develop a procedure to solve such problems.
3. To incorporate optimization component in the Decision Support System.

Parameters
The general parameters of a transportation problem are as follows:

a. Resources- The resources are those elements that can be transported from sources to destinations. Examples of discrete resources are goods, machines, tools, people, cargo, etc. Continuous resources include energy, liquid and money.

b. Locations- The locations are points of supply, recollection, depot, nodes, railway stations, bus stations, loading port, seaports, airports, refuelling depots, or school.

c. Transportation modes- The transportation modes are the form of transporting some resources to locations. The transportation modes use water, space, air, road, and cable. The form of transport have different infrastructure, capacity, times, activities and regulations. Example of transportation modes are ship, aircraft, truck, train, pipeline, motorcycle and others.

Variables
The transportation logistic designer often has to choose among various means of transportation for transporting his commodity. The conventional transportation problem usually minimizes only the transportation cost. But in situations such as delivery of perishable goods, emergency services etc. transportation time is also very important. In real-life application there exist a number of situations where a decision maker would like a trade-off on cost attain a certain degree of time advantage.

Methodology
1. The formulation of quadratic transportation problem: In conventional transportation problem only two indices are considered for supply and demand. In the proposed work a quadratic transportation problem will be formulated with 3 indices. The third index that can be considered is mode of transportation, risk involved in transportation, types of commodity, from which the one best suited in this study will be taken.

2. Lexicographic optimization: Lexicographic optimization approach will be used to solve above mentioned problem. In lexicographic approach criteria are ordered by priority
(preference or significance). Here an arbitrary improvement is obtained for the most important criteria through any loss in other less important criteria.

3. **Transportation Decision Support System**: A decision support system will be designed and developed to incorporate the transportation problem model and its solution procedure preferably using MATLAB/C.

**Design and Development of DSS**

The proposed decision support system will be designed using the Life cycle approach (Figure 1), where after defining the problem (intelligence phase), solution procedure will be developed (design phase) and will be applied based on the nature of the problem (choice stage). The solution will then be implemented (implementation stage) and will be evaluated for determining if the anticipated results were achieved (monitoring stage).

![Figure 1: The Life Cycle approach](image)

**Components of DSS**

1. **The database**: The DSS includes database containing relevant data for the situation and managed by a database management system.

2. **The model-base**: The model management subsystem will include the optimization model for solving the quadratic transportation problem to provide effective decision-making platform.

3. **The user interface**: The user interface system will establish communication between the computer and the decision maker.
References


