Supply Chain Network Optimization Model for Third Party Logistics

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Abstract

Supply chain management (SCM) includes the management of the movement and storage of goods and services from their point of origin to the point of consumption.

A Supply Chain Network (SCN) is an evolution of the basic supply chain therefore affects an organization's performance and profit. Since it plays a vital role in survival of a company it should be designed with more attention to assure good performance and profit.

Third party logistics (3PL) describes businesses that provide one or many of a variety of logistics-related services. Types of services would include public warehousing, contract warehousing, transportation management, distribution management, freight consolidation etc.

This thesis focuses on the development of a mathematical model using integer linear programming (ILP) for the purpose of optimizing the multi echelon supply chain network for multi products to minimize the transportation and damage costs hence increasing the profit for the third party logistics company.

Key words: Supply chain management, Supply chain network, ILP, third party logistics, modelling, multi echelon, and multi products.

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CHAPTER 1. INTRODUCTION

Supply chain plays a vital role in the survival of a company or business as it involves the activities for designing, manufacturing, delivering and using a product or a service. The strength of a company's supply chain determines its competitiveness in the market. An organization and its supply chain is considered as a single entity in the supply chain management.it facilitates in systematically understanding and managing different activities required for coordinated flow of products and services for ultimate customer satisfaction. Figure below illustrates a very basic supply chain.

Figure 1.1: A Basic Supply Chain

1.1. Supply Chain Network

A supply chain network (SCN) consists of the network structure with various decisions from strategic decisions on location and capacities of facilities to operational and tactical concerns about transportation or inventory management policies [1]. A network design is critical in supply chain as it influences the performance and cost. In this thesis the main focus is on monetary objectives. It is achieved by optimizing a SCN with the aim of minimizing total costs of network hence contributing to the organization's overall profit.

1.2. Logistics in Supply Chain

Purpose of the logistics is to connect the supplier to the customer. By serving as a bridge it fills the gap between the market demands and the supply sources.to make it possible all the components of the logistics system like the warehousing network, the transportation network, the inventory control system and the supporting information system come into operation. Main objective is to deliver the right product to the right place at right time with the minimum cost possible. The objective of the logistics system is maintaining the balance between the customer service and cost. Logistics makes it possible to deliver products to the customer anywhere irrespective of its manufacturing location [2].

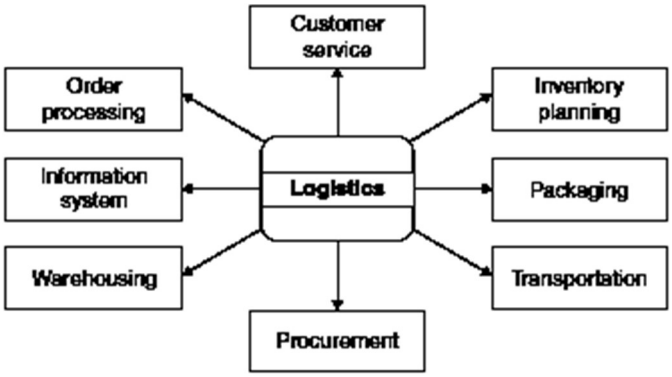


Figure 1.2: A Basic Logistics Network

1.3. Third Party Logistics

In the recent years third party logistic (3PL) has become more important for logistic sector. By achieving cost reduction companies try to provide customer satisfaction. In order to avoid any obstacles due to logistics involvement these days organizations prefer special firms for some or all of their logistics operations. Third party logistics (3PL) is emerging and developing rapidly to fulfill the demands for advanced logistics services. Most commonly provided services are related to transportation, warehousing, freight consolidation and distribution, product marking, labeling and packaging, inventory management, cross docking, product returns, order management, and logistics information systems. Therefore, third party logistics

can be defined as relationships between interfaces in the supply chains and third-party logistics providers, where logistics services are offered, from basic to customized ones, in a shorter or long term relationship, with the aim of effectiveness and efficiency [3].

1.4. Transportation in Pakistan

For the advancement of any economic system a strong and reliable transport and communication sector is required. The China Pakistan Economic Corridor (CPEC) is also going to build up an efficient transport and communication system. It will have a positive impact on factors as trade stimulation , markets extension, increased employment, increased social welfare and will help to stabilize the prices.

Different Transportation Modes in Pakistan:

- **Roads:**

  Currently National Highway Authority (NHA) network comprises of 39 national highways, motorways, expressways, and strategic roads. Current length of this network is 12,131 km. Geographically the River Indus bisects Pakistan in to two halves. Eastern segment is historically well developed. In order to bring the Western segment at par with the Eastern half, NHA is constructing numerous bridges across river Indus in addition to investing and paying extra attention to the development of west.

- **Railways:**

  In past railway was the primary mean of the transportation for bulk cargo and large number of passenger movement. Due to lack of attention payed by the Pakistani government the condition of railway networks has deteriorated over time. There is huge difference between the budget allocation for railway and roads. Currently the freight carried by railways is 4.77 million tons in 2016 which was 3.3 million tons in 2015 while it carried 52.2 million passengers in 2016 which were 50 million in 2015. So it can be said that there have been gradual improvements in Pakistan railways.

- **Airways:**

Pakistan has 27 operational airports. For international flights 9 airports are used whereas for domestic use 13 airports are used and 1 is for private aviation use. Airways in Pakistan have the capacity to facilitate 17 million passengers and 7 billion tons of cargo yearly. Among the major airports the Jinnah International situated in Karachi is the busiest one.

Pakistan International Airline (PIA) contributes 73% of passenger traffic and also handles nearly all the freight forwarding business. Pakistani airports are directly connected with UK, USA and Middle East countries. The air travelling cost per kilometer is very expensive in Pakistan.

1.5. Optimization with Integer Linear Programming

Linear programming is a mathematical modeling used for optimization. In it a linear function is either maximized or minimized when subjected to various constraints. This technique has been proved helpful in many field like business planning and engineering. The solution of this technique finds the optimum value largest or smallest depending on the case or problem of the linear function called an objective function subject to constraints expressed as inequalities usually. This research is carried out using simplex method. The reason for selection of this method is that it is flexible for application to large scale problems. It converges to global optimal solutions. It has readily available efficient software packages. Mentioned below is the procedure of the simplex method:

Step-1: First of all, the objective function is checked if it's being maximized or minimized. If it's a minimization function, then it is converted to maximization by multiplying with minus one that is Minimum Z = - Maximum(-z)

Step-2: Right hand side values of the constraints are checked for non-negativity. If any value is negative, then it is multiplied by minus one in order to make it non negative.

Step-3: Then Slack/ Surplus variables are introduced in the constraints to convert all the inequality constraints to equations.

Step-4: The first column of the simplex table is filled with an obtained initial basic feasible solution.

Step-5: The net evolutions $\Delta j = Zj - Cj$ (j=1, 2....n) is computed by using the relation $Zj - Cj = CB\ Xj - Cj$. After this the sign of all net evolutions are observed. If all are non-negative, then it is an optimum solution and if at least one is negative then proceed to the next step.

Step-6: In case of more than one negative evolution the most negative one is selected. The corresponding column is called entering column. If all the values in this column are ≤ 0, then it is an unbounded solution. If at least one value is > 0, then the corresponding variable enters the basis.

Step-7: The ratio {XB / Entering column}is computed and the minimum of these ratios is selected. The row containing the minimum ratio is called the leaving row. The common element which is in both entering column and leaving row is known as the key element or pivotal element of the table.

Step-8: The key element is converted to unity by dividing its row by the leading element itself and all other elements in its column to zeros by using elementary row transformations.

Step-9: From step 5 onwards the process is repeated until either an optimum solution or an unbounded solution is obtained.

CHAPTER 2. CASE STUDY

This research is based on the case study. The organization aimed to increase the profit by reducing its transportation cost. The organization selected for this research is Capital Group of Companies. It was established in 1982 with the setup of Capital Steel Industries in Islamabad. Starting from steel billet and ingot production. CSI expanded with the addition of a re-rolling division in 1989. Since then the Company has been going strong and is continually looking to progress into newer ventures.

Capital Marketing Services (CMS) is an independent logistics service provider that began its operations in 1998. Initially conceived as a distribution company, over the years it has progressed and is now involved in providing transportation and warehousing services to its clients. CMS manages an extensive transportation network, covering haulage in nearly every major city and town of Punjab, Sindh and KPK.

Transportation

The type of transportation service varies depending upon the source and destination of the haulage and is categorized into primary and secondary transportation. Primary transportation entails providing freight transportation service from the manufacturer's warehouse or manufacturing unit to its secondary warehouses or depots. Secondary transportation encompasses transporting freight from secondary warehouses to various distributors or dealers. CMS provides both primary and secondary transportation services to its clients.

To cover the vast network, CMS has deployed new & modern trucking fleet of over 250 trucks, ranging from 6-wheeler trucks with a carrying capacity of 10 tons to 22-wheeler trucks with a carrying capacity 70 tons. The diversity of the CMS' fleet enables it to provide fast, efficient and reliable delivery solutions to customers.

Warehousing

CMS also provides its clients with warehousing services. The warehouses are located in Islamabad and KPK and have a combined area of over 100,000 square feet.

CHAPTER 3. LITERATURE REVIEW

Since supply chain network is a very critical component of supply chain management a lot of research has been carried out on its designing and optimal functioning. The focus of thesis is on optimization of a distribution network in supply chain for a third party logistics company.

P. Serdaris et al [4] explain that logistics when integrated with supply chain then all the activities and operation starting from manufacturing, warehousing, transporting, marketing and distribution serve an important role in helping an enterprise achieve a competitive advantage.

Service providers have special expertise needed by a supply chain be it to provide services to the producers, distributors, retailers or end customers. Some of the common service providers in supply chain are the logistics providers. These are basically the trucking companies and public warehouse companies that provide transportation and warehousing services [5].

Hosang Jung [6] describes a third party logistics company an external facilitator who manages, controls and delivers logistics activities on behalf of an organization. It collects shipments from the manufacturers and ship to their distribution centers. The most frequently cited benefit of using a 3PL provider is that it allows a manufacturer to focus on its competencies.

Since there is always a room for improvement and to survive in this competitive environment each company be it a manufacturer or a service provider keeps on optimizing its processes and activities. Several techniques and methods have been adopted for optimization. The focus of this thesis is reduction of a transportation cost which is a part of the objective function.

Muztoba Ahmad Khan [7] describes optimization as the best and effective way of using resources and technology. Quantitative models and mathematical tools such as linear programming allows for better result. Nowadays various problems of operational planning for transportation problems are solved by mathematical methods. Linear programming method is used to model most of these transportation problems.

According to R.O.Edokpia et al [8] the desire for a company to expand with better sales and larger market point to the fact that the transportation and distribution costs will keep on incurring with the movement of goods and services. Normally linear programming is used for the transportation cost reduction due to the simplicity of the procedure.

J.Reeb et al [9] states that one of the problem faced by the managers is the allocation of scarce resources and linear programming is an optimal way of doing it. Since its one of the most commonly used operations research tool it has helped many manufacturing, financial and series organizations in decision making.

According to Dr. J. Sengamalaselvi [10] as far optimization is concerned modeling of transportation problem is fundamental in solving real life problems in linear programming. MATLAB is used for such mathematical modelling. Several methods like Simplex, North West Corner Rule, Least Count Method, Vogel's Approximation Method and Modi method are used for solving such optimization problems.

Namrata Tripathi et al [11] states that one of the real world problems is the optimization which is widely used in many areas of mathematics, engineering, science, business and economics. Optimization therefore can be described as a process of selecting a final solution amongst a number of possible options such that requirement is best satisfied. The Simplex Algorithm developed by G.B. Danzig is used to solve linear programming problems. Researchers have used MATLAB and MS EXCEL solver as optimizing tools in this paper.

CHAPTER 4. SUPPLY CHAIN NETWORK MODEL

A supply chain network model is being formulated considering some important factors like the supply capacity of the warehouses, demand of the distribution centers, distance between each warehouse and distributors, transportation cost per trip of shipment to the distributors from each warehouse.

4.1. Problem Description

In this research a mathematical model is formulated represents a mutli-product supply chain network for a third party logistics providing company. It comprises of 2 warehouses located in Rawat and Lawrencepur respectively from which the product is transported to 43 distribution centers in northern region of Punjab and Khyber Pakhtoonkhwa. The supply capacities and demands are known. Transportation costs for transporting products from the warehouses to the distribution centers are known. Objective is to minimize the total cost which is the sum of the damage cost and the transportation cost between the warehouses to distribution centers.

4.1.1. Standard Formulation

The supply chain network design problem is formulated as an integer linear programming model. The model will work on the data obtained for one month for ease of calculation. The following assumptions have been used in this problem:

1. It is a multi-product model so in this research 2 products are considered cooking oil and a banaspatee ghee
2. The model is applicable for a 3PL company therefore only transportation of products from the warehouses to the distribution centers is considered
3. The supply capacity of the warehouses and demands of the distribution centers are known
4. Since it's a multiple product model therefore 2.5 liters or kg is considered as a single unit for each type of the product for the ease of calculations and average units per truckload for each type is calculated as:

- Average units/truckload for cooking oil = [(no of cartons x total units in 2.5L x no of tins/ bottles / pouches in carton) + (no of cartons x total units in 3L x no of tins/bottles / pouches in carton) + (no of cartons x total units in 4.5L x no of tins/bottles / pouches in carton) + (no of cartons x total units in 5L x no of tins/ bottles/ pouches in carton)]

Average units/truckload for cooking oil = [(a x b x c) + (a x d x c) + (a x e x c) + (a x f x c)]

Where: a = Number of cartons b = Total units in 2.5L

c = Number of tins/ bottles/ pouches in a carton d = Total units in 3L

e = Total units in 4.5 L f = Total units in 5L

e.g. Average units/truckload for cooking oil = (80*1*6) +(55*1.2*6) + (35*1.8*4) +(35*2*5) +(30*2*4) = 1718 units

- Average units/truckload for banaspatee ghee = [(no of cartons x total units in 2.5L x no of tins/ pouches in carton) + (no of cartons x total units in 5L x no of tins/ pouches in carton)]

Average units/ truckload for banaspatee ghee = [(a x h x c) + (a x i x c)]

Where: a = Number of cartons h = Total units in 2.5kg

c = Number of tins/ bottles/ pouches in a carton i = Total units in 5kg

e.g. Average units/truckload for banaspatee ghee = (35*1*6) +(60*2*5) +(50*2*4) = 1210 units

- Total units/ truckload = 1718 + 1210 = 2928 units
- Average unit / case = total units/ truckload = 2929 / 380 = 7.705263 units

5. Transportation cost for each product is calculated using the following formula:

- Transportation cost per trip= Fixed transportation cost per km x distance between the warehouse and the distribution center

  Transportation cost per trip= m x n

  Where m = Fixed average transportation cost per km (i.e. Rs. 55/Km)

  n = Distance between the warehouse and the distribution center

- Transportation cost per unit = Transportation cost per trip/ Average units per truckload

  Transportation cost per unit = p / q

  Where p = Transportation cost per trip

  q = Average units per truckload

Sr. No	Cities	Distance in Km	Quantity of dalda cooking oil supplied	Quantity of dalda Banaspatee ghee supplied	Transportation cost per unit (Cij)	Xij
1	Abbottabad	164	-	-	3.08	0
2	Attock	105	-	-	1.97	0
3	Balakot	226	-	-	4.25	0
4	Batkhela	233	-	-	4.38	0
5	Barakahu	31	74,000	32,000	0.58	106000
6	Chak Beli Khan	48	29,000	16,000	0.90	45000
7	Chinari ajk	200	33,000	18,000	3.76	51000
8	Dargai	180	-	-	3.38	0
9	Dir	333	-	-	6.26	0
10	Fateh Jang	66	-	-	1.24	0
11	Garhi Dupatta ajk	174	-	-	3.27	0
12	Ghari Habibullah	216	-	-	4.06	0
13	Gilgit	541	16,000	8,000	10.16	24000
14	Hajira ajk	124	20,000	11,000	2.33	31000
15	Haripur	123	-	-	2.31	0
16	Hassan Abdal	83	-	-	1.56	0
17	Havellian	147	-	-	2.76	0
18	Hazro	100	-	-	1.88	0
19	Islamabad Capital	29	1,163,000	388,000	0.54	1551000
20	Jand	142	16,000	9,000	2.67	25000
21	Jatlan ajk	112	-	-	2.10	0
22	Kahuta	34	49,000	21,000	0.64	70000
23	Kohat	203	-	-	3.81	0
24	Kotli AjK	115	13,000	7,000	2.16	20000
25	Lora	80	10,000	5,000	1.50	15000
26	Mansehra	186	-	-	3.49	0
27	Mardan	171	-	-	3.21	0
28	Mirpur AjK	103	56,000	24,000	1.93	80000
29	Mong	134	28,000	12,000	2.52	40000
30	Murree	86	31,000	17,000	1.62	48000
31	Muzafarabad ajk	154	72,000	39,000	2.89	111000
32	Nakyal ajk	152	7,000	4,000	2.86	11000
33	Oghi	219	-	-	4.11	0

34	Peshawar	212	-	-	3.98	0
35	Pindigheb	124	42,000	18,000	2.33	60000
36	Pallandri ajk	86	23,000	12,000	1.62	35000
37	Rawalakot ajk	97	26,000	14,000	1.82	40000
38	Rawalpindi	23	1,425,000	475,000	0.43	1900000
39	Sehnsa ajk	84	20,000	11,000	1.58	31000
40	Sihala	10	84,000	36,000	0.19	120000
41	Skardu	663	8,000	4,000	12.45	12000
42	Swabi	133	-	-	2.50	0
43	Taxila	53	28,000	12,000	1.00	40000

Table 4.1: Transportation cost per unit of each distribution center from warehouse in Rawat and total quantity supplied to each distribution center

Sr. No	Cities	Distance in Km	Quantity of dalda cooking oil supplied	Quantity of dalda banaspatee ghee supplied	Transportation cost per unit (Cij)	X_{ij}
1	Abbottabad	92	113,000	37,000	1.73	150000
2	Attock	18	56,000	24,000	0.34	80000
3	Balakot	152	18,000	12,000	2.86	30000
4	Batkhela	144	6,000	4,000	2.70	10000
5	Barakahu	86	-	-	1.62	0
6	Chak Beli Khan rw	114	-	-	2.14	0
7	Chinari ajk	208	-	-	3.91	0
8	Dargai	92	45,000	3,000	1.73	48000
9	Dir	244	45,000	30,000	4.58	75000
10	Fateh Jang	52	35,000	15,000	0.98	50000
11	Garhi Dupatta ajk	182	6,000	4,000	3.42	10000
12	Ghari Habibullah	143	6,000	4,000	2.69	10000
13	Gilgit	467	-	-	8.77	0
14	Hajira ajk	208	-	-	3.91	0
15	Haripur	51	49,000	21,000	0.96	70000
16	Hasan Abdal	18	42,000	18,000	0.34	60000
17	Havellian	73	32,000	13,000	1.37	45000
18	Hazro	13	25,000	10,000	0.24	35000

19	**Islamabad Capital**	**70**	**-**	**-**	**1.31**	**0**
20	**Jand**	**96**	**35,000**	**15,000**	**1.80**	**50000**
21	**Jatlan ajk**	**209**	**21,000**	**9,000**	**3.93**	**30000**
22	**Kahuta**	**114**	**-**	**-**	**2.14**	**0**
23	**Kohat**	**186**	**42,000**	**28,000**	**3.49**	**70000**
24	**Kotli AK**	**197**	**-**	**-**	**3.70**	**0**
25	**Lora**	**127**	**-**	**-**	**2.39**	**0**
26	**Mansehra**	**112**	**66,000**	**44,000**	**2.10**	**110000**
27	**Mardan**	**82**	**84,000**	**56,000**	**1.54**	**140000**
28	**Mirpur AK**	**200**	**-**	**-**	**3.76**	**0**
29	**Mong**	**293**	**-**	**-**	**5.50**	**0**
30	**Murree**	**138**	**-**	**-**	**2.59**	**0**
31	**Muzafarabad**	**162**	**-**	**-**	**3.04**	**0**
32	**Nakyal**	**235**	**-**	**-**	**4.41**	**0**
33	**Oghi**	**145**	**24,000**	**16,000**	**2.72**	**40000**
34	**Peshawar**	**125**	**276,000**	**184,000**	**2.35**	**460000**
35	**Pindigheb**	**105**	**54,000**	**36,000**	**1.97**	**90000**
36	**Pallandri ajk**	**170**	**-**	**-**	**3.19**	**0**
37	**Rawalakot**	**181**	**-**	**-**	**3.40**	**0**
38	**Rawalpindi**	**75**	**-**	**-**	**1.41**	**0**
39	**Sehnsa ajk**	**169**	**-**	**-**	**3.17**	**0**
40	**Sihala**	**86**	**-**	**-**	**1.62**	**0**
41	**Skardu**	**589**	**18,000**	**12,000**	**11.06**	**30000**
42	**Swabi**	**44**	**66,000**	**44,000**	**0.83**	**110000**
43	**Taxila**	**39**	**48,000**	**32,000**	**0.73**	**80000**

Table 4.2: Transportation cost per unit of each distribution center from warehouse in Lawrencepur and total quantity supplied to each distribution center

4.2. Mathematical Modeling

In order to formulate a mathematical model following factors are considered:

- Objective function
- Decision variables
- Constraints
- Non Negativity constraints

4.2.1. Parameter Definition

i= representation of the number of warehouses (i=1, 2)

j= representation of the number of distribution centers (j=1, 2, 3…43)

x_{ij} = quantity supplied from warehouses to distribution centers

c_{ij} = Transportation cost per unit from warehouses to distribution centers

4.2.2. Objective Function

Objective function is basically a mathematical representation of the objective of the problem. In our case the objective is to minimize the total cost comprising of the damage cost which is calculated as A = 0.1% of total weight*cost of 1 unit*no. of trips in month, transportation cost "C_{ij}" for transporting "x_{ij}" units from the warehouses to the distribution centers where "i" is the number of warehouses and "j" is the number of distribution centers.

So the objective function can be mathematically expressed as:

Total cost = [Min (Transportation cost)] + Damage Cost

$Z = [\text{Min}\{(\sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij}X_{ij}) + (\sum_{i=n+1}^{m}\sum_{j=n+1}^{m} C_{ij}X_{ij})\}] + A$

4.2.3. Decision Variables

x_{ij} = Quantity supplied from warehouses to distribution centers

4.2.4. Constraints

Constraints are known as the limitations or restrictions on the optimization problem which need to be satisfied. In our case we have supply and demand constraints. The problem under consideration involves 2 supply constraints and 43 demand constraints. The less than or equal to sign in supply constraints shows that the supply capacity of each first marketing warehouse may be less than or equal to the amount shown but never greater than it. The

greater than or equal to sign in demand constraints shows that the demand of each distribution center maybe greater than or equal to the amount shown but never less.
As per the requirements of the model its constraints are stated below:

Supply constraints:

$\sum_{j=1}^{43} X_{1,j} \leq 1500000$ ---------- warehouse 1
$\sum_{j=1}^{43} X_{2,j} \leq 800000$ ---------- warehouse 2

Demand constraints:

$X_{i,1} \geq 150000$	$X_{i,15} \geq 70000$	$X_{i,29} \geq 40000$	$X_{i,43} \geq 120000$
$X_{i,2} \geq 80000$	$X_{i,16} \geq 60000$	$X_{i,30} \geq 48000$	
$X_{i,3} \geq 30000$	$X_{i,17} \geq 45000$	$X_{i,31} \geq 111000$	
$X_{i,4} \geq 10000$	$X_{i,18} \geq 35000$	$X_{i,32} \geq 11000$	
$X_{i,5} \geq 106000$	$X_{i,19} \geq 1551000$	$X_{i,33} \geq 40000$	
$X_{i,6} \geq 45000$	$X_{i,20} \geq 75000$	$X_{i,34} \geq 460000$	
$X_{i,7} \geq 51000$	$X_{i,21} \geq 30000$	$X_{i,35} \geq 150000$	
$X_{i,8} \geq 48000$	$X_{i,22} \geq 70000$	$X_{i,36} \geq 35000$	
$X_{i,9} \geq 75000$	$X_{i,23} \geq 70000$	$X_{i,37} \geq 40000$	
$X_{i,10} \geq 50000$	$X_{i,24} \geq 20000$	$X_{i,38} \geq 476425$	
$X_{i,11} \geq 10000$	$X_{i,25} \geq 15000$	$X_{i,39} \geq 31000$	
$X_{i,12} \geq 10000$	$X_{i,26} \geq 110000$	$X_{i,40} \geq 120000$	
$X_{i,13} \geq 24000$	$X_{i,27} \geq 140000$	$X_{i,41} \geq 42000$	
$X_{i,14} \geq 31000$	$X_{i,28} \geq 80000$	$X_{i,42} \geq 110000$	

Table 4.3: Demand Constraints

Non Negativity constraints:

$X_{ij} \geq 0$

4.3. Optimization Softwares and Procedures

An optimized solution under respective constraints were obtained using integer linear programming in two softwares MATLAB and MS EXCEL Solver. Both the softwares used simplex method of linear programming for obtaining the results. The steps and calculations involved in both the softwares are mentioned below:

4.3.1. Microsoft Excel Solver

Steps involved in optimization through this software are here under:

1. First of all, prepare a worksheet properly defining the objective function, decision variables and the constraints.

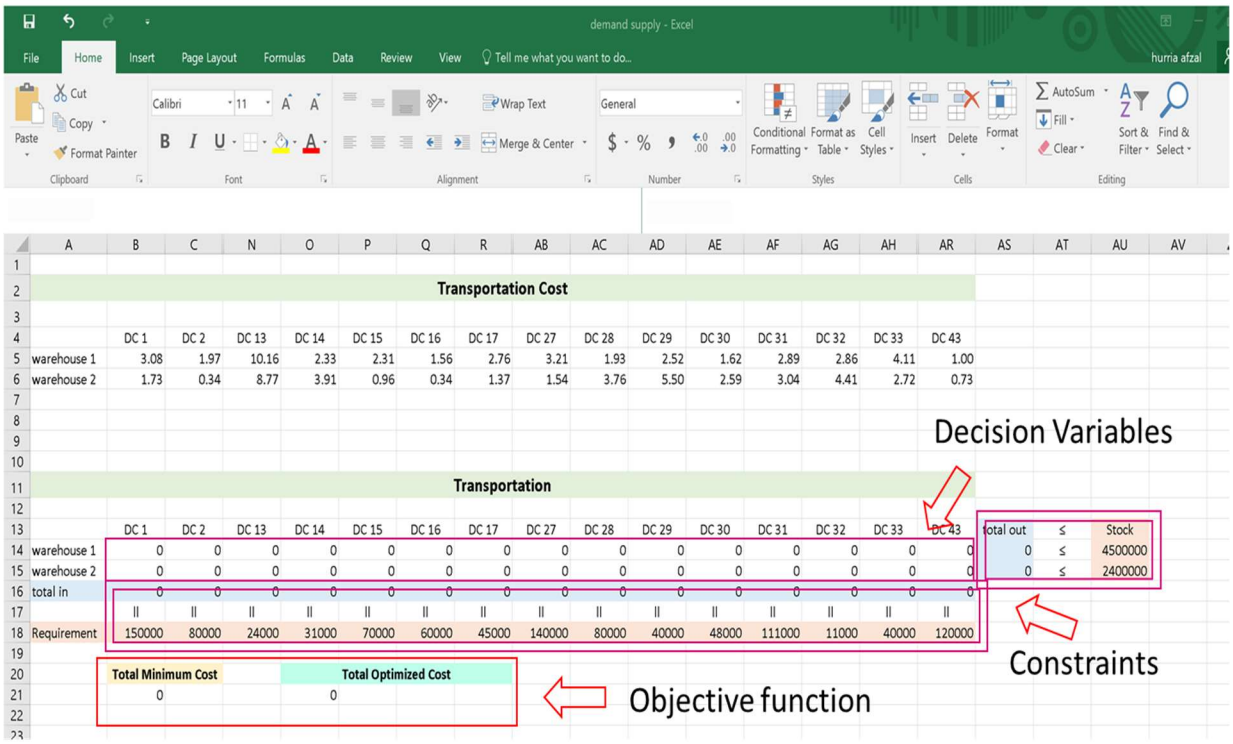


Figure 4.1 Excel sheet showing objective function, decision variables and constraints

2. Open data tab and click solver a dialogue box will appear asking for the range for objective function, kind of optimization like maximize or minimize etc., range for decision variables, constraint ranges, non-negativity constraint, and last the method of solving the linear problem. After giving the desired values press the solve button to proceed further.

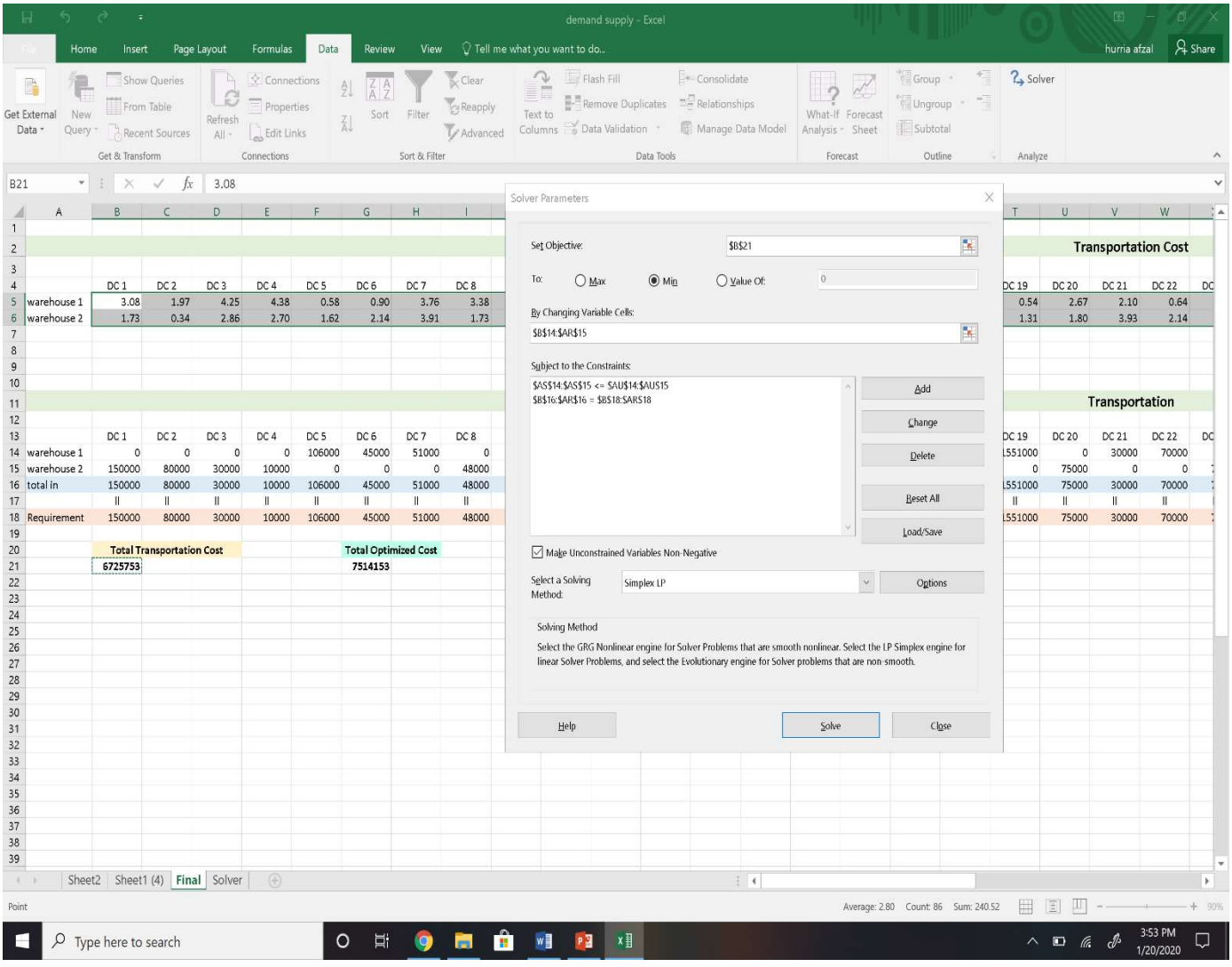


Figure 4.2: Excel worksheet showing how to input objective function, decision variables and constraints in solver

3. After pressing the solve button a dialogue box appears select the option named keep solver solution and press ok. After that the existing values in the previously prepared sheet will be replaced with the new result values.

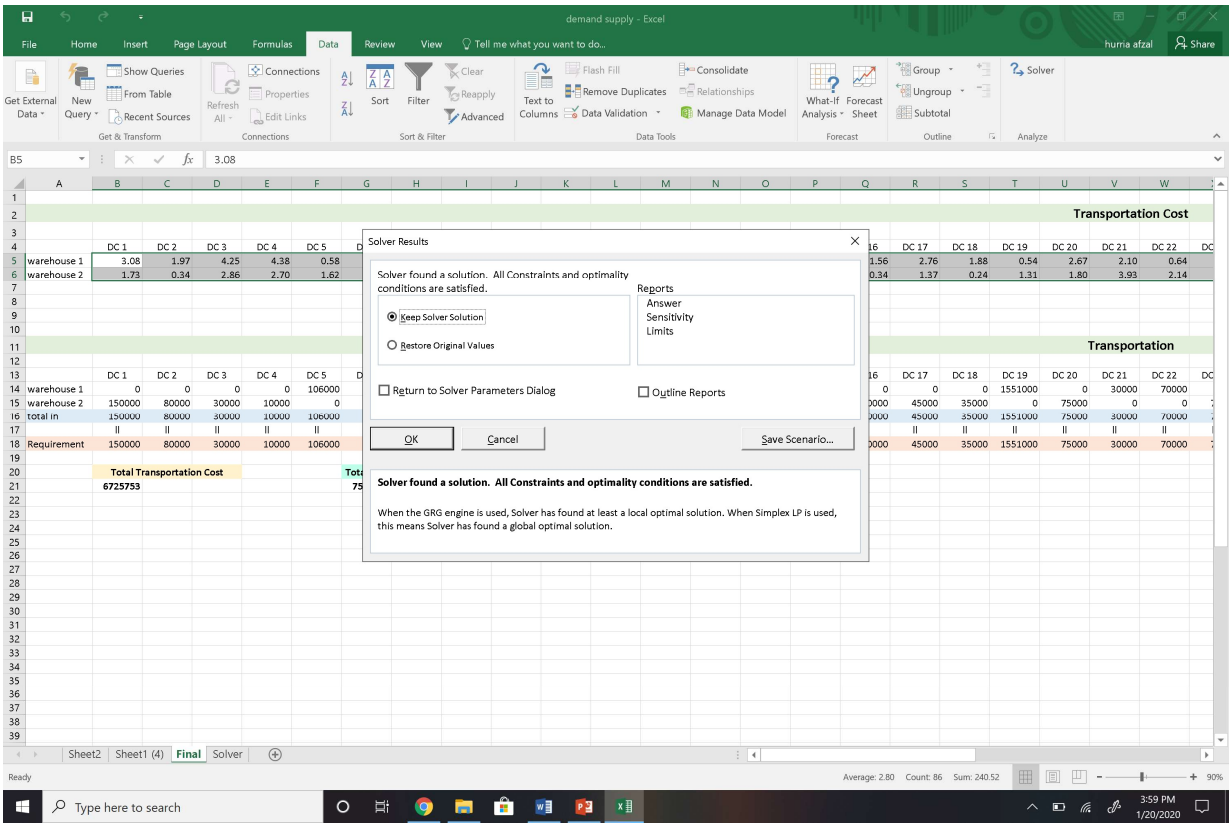


Figure 4.3: Excel worksheet showing solver results

4.3.2. MATLAB

Mentioned below is a pseudo code for the integer linear programming using simplex method. After running the programm the results were obtained.

```
S = [4500000 2400000];
D = [150000 80000 30000 10000 106000 45000 51000 48000 75000 50000 10000 10000
24000 31000 70000 60000 45000 35000 1551000 75000 30000 70000 70000 20000 15000
110000 140000 80000 40000 48000 111000 11000 40000 460000 150000 35000 40000
476425 31000 120000 42000 110000 120000];
C = [3.08 1.97 4.25 4.38 0.58 0.90 3.76 3.38 6.26 1.24 3.27 4.06 10.16 2.33 2.31 1.56 2.76
1.88 0.54 2.67 2.10 0.64 3.81 2.16 1.50 3.49 3.21 1.93 2.52 1.62 2.89 2.86 4.11 3.98 2.33 1.62
1.82 0.43 1.58 0.19 12.45 2.50 1.00
   1.73 0.34 2.86 2.70 1.62 2.14 3.91 1.73 4.58 0.98 3.42 2.69 8.77 3.91 0.96 0.34 1.37 0.24
1.31 1.80 3.93 2.14 3.49 3.70 2.39 2.10 1.54 3.76 5.50 2.59 3.04 4.41 2.72 2.35 1.97 3.19 3.40
1.41 3.17 1.62 11.06 0.83 0.73];
if sum(S)<sum(D)

f = C(:);

for i=1:nw
   c=c+1;
   for j=1:nc
      A(c,ind(i,j))=1;
   end
   b(c)=S(i);
end

for j=1:nc
   c=c+1;
   for i=1:nw
      A(c,ind(i,j))=-1;
   end
   b(c)=-D(j);
```

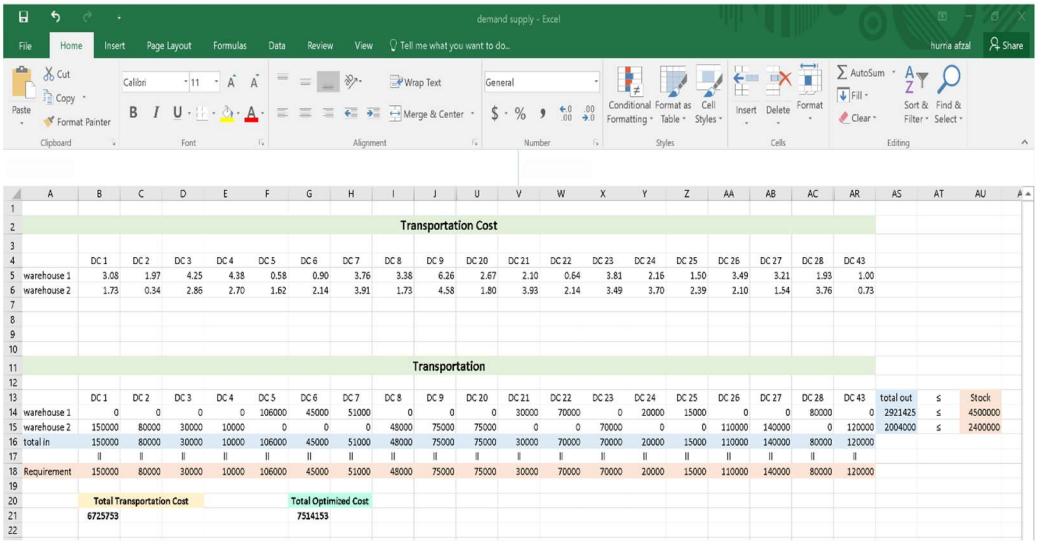
Table 4.4: MATLAB optimization pseudo code

CHAPTER 5. RESULTS AND ANALYSIS

In this chapter the outcomes obtained as a result of mathematical modelling for cost optimization for a third party logistics company using simplex method of integer liear programming using two softwares are discussed. Later the conclusion of this research work will be discussed showing how effective and efficient this model can be for a 3PL company if applied.

5.1. Results of Microsoft Excel Solver

The results as shown below tell us that the supply to each distribution center from the respective warehouse is equal to the demand of each distribution center. Also the total quantity out means the quantity delivered is less than the supply capacity of both the warehouses. Since all the calculations are performed on the basis of real time data for a month only therefore the optimal transportation cost calculated as per the model is Rs.6725753. As per the objective function which comprised of sum of minimized transportation cost and the damage cost is calculated as Rs.7514153. It also showed the optimum quantity to be delivered to each distribution center from both the warehouses. Below Figure shows the excel results also few columns and rows are hidden for ease of view.



Transportation Cost

	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8	DC 9	DC 20	DC 21	DC 22	DC 23	DC 24	DC 25	DC 26	DC 27	DC 28	DC 43
warehouse 1	3.08	1.97	4.25	4.38	0.58	0.90	3.76	3.38	6.26	2.67	2.10	0.64	3.81	2.16	1.50	3.49	3.21	1.93	1.00
warehouse 2	1.73	0.34	2.86	2.70	1.62	2.14	3.91	1.73	4.58	1.80	3.93	2.14	3.49	3.70	2.39	2.10	1.54	3.76	0.73

Transportation

	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8	DC 9	DC 20	DC 21	DC 22	DC 23	DC 24	DC 25	DC 26	DC 27	DC 28	DC 43	total out	≤	Stock
warehouse 1	0	0	0	0	106000	45000	51000	0	0	0	30000	70000	0	20000	15000	0	0	80000	0	2921425	≤	4500000
warehouse 2	150000	80000	30000	10000	0	0	0	48000	75000	75000	0	0	70000	0	0	110000	140000	0	120000	2004000	≤	2400000
total in	150000	80000	30000	10000	106000	45000	51000	48000	75000	75000	30000	70000	70000	20000	15000	110000	140000	80000	120000			
	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=			
Requirement	150000	80000	30000	10000	106000	45000	51000	48000	75000	75000	30000	70000	70000	20000	15000	110000	140000	80000	120000			

Total Transportation Cost	Total Optimized Cost
6725753	7514153

Figure 5.1: Excel worksheet showing solver results of minimized transportation and total cost

5.2. Results of MATLAB

A mathematical model was formulated involving cost of supplies, quantity of items to be delivered and supply and demand constraints. The model used "linprog" solver using simplex method for optimization of transportation and as well as total minimum cost. It also showed the optimum quantity to be delivered to each distribution center from both the warehouses. The value obtained as result for minimized transportation cost was Rs.6725753 whereas total minimum cost was Rs.7514153. Results are illustrated by the figures below:

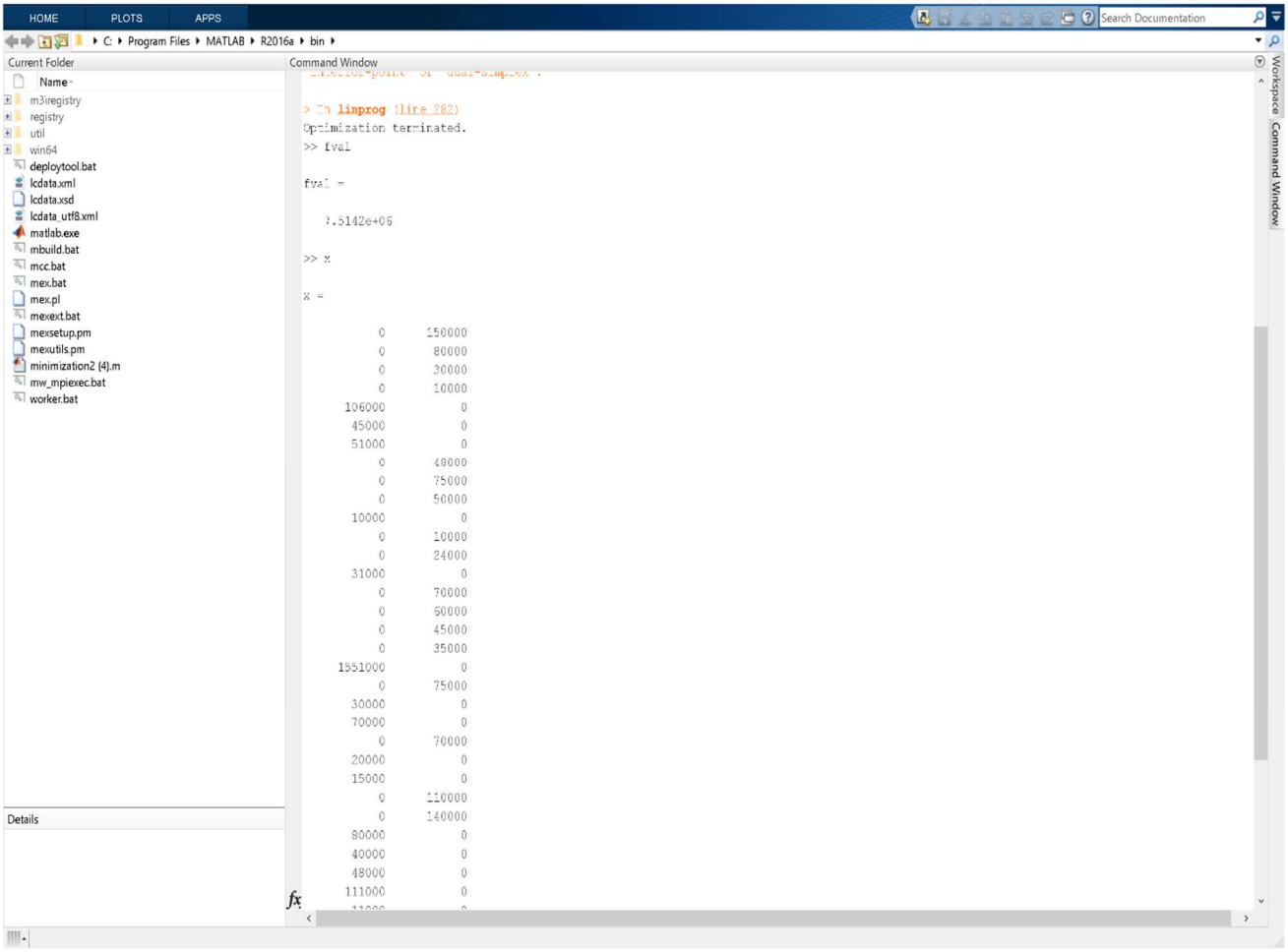


Figure 2.2: MATLAB results of minimized transportation cost

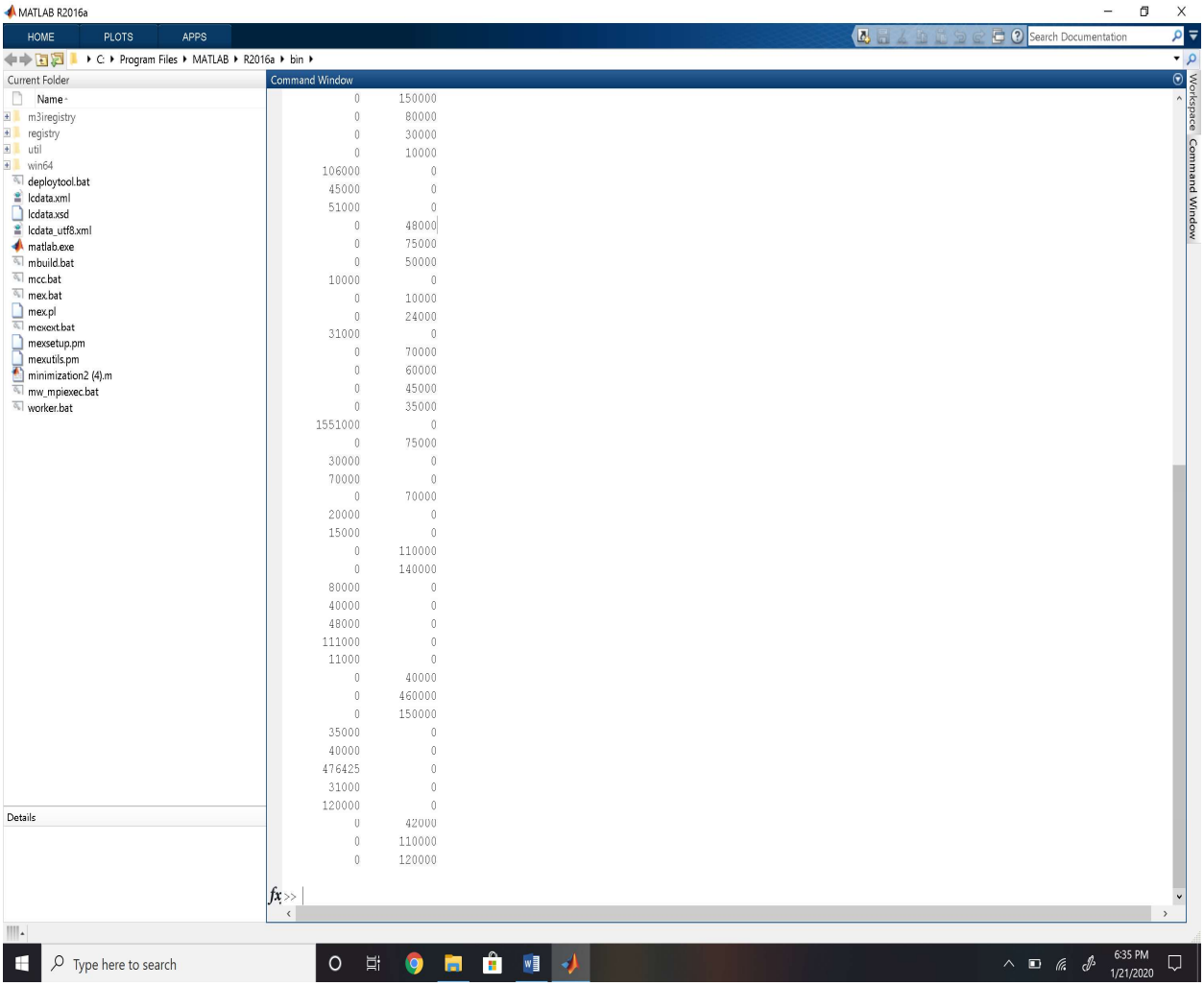


Figure 5.3: MATLAB results showing minimized total cost

For the validation of the model being formulated earlier it was applied to a similar case study of J & J Essential Products (Pvt.) Ltd. is primarily a cosmetics and toiletries products manufacturing industry. However, they also produce some highly demanding products, i.e. electric bulb, mosquito coil etc. The Company has set up regional offices in Dhaka, Chittagong and Bogra along with warehouse facilities. There are seven distributor's warehouses where the goods are delivered from company's warehouses. The company sends goods through four of its own vehicles and use public transport services. The company's sales and distribution costs account for 19% of total cost [7].

For the minimization of the transportation cost the following data was obtained for the mosquito coils :

Distributor's warehouse / Company's warehouse	Dhaka A_1	Chittagong A_2	Bogra A_3	Stock
Dhaka (B1)	$C_{2,1}$=15	$C_{2,1}$=160	$C_{3,1}$=100	b_1=1168
Chittagong (B2)	$C_{1,2}$=160	$C_{2,2}$=12	$C_{3,2}$=260	b_2=1560
Rangpur (B3)	$C_{1,3}$=154	$C_{2,3}$=315	$C_{3,3}$=56	b_3=1439
Barisal (B4)	$C_{1,4}$=245	$C_{2,4}$=410	$C_{3,4}$=190	b_4=986
Rajshahi (B5)	$C_{1,5}$=130	$C_{2,5}$=290	$C_{3,5}$=58	b_5=1658
Sylhet (B6)	$C_{1,6}$=125	$C_{2,6}$=427	$C_{3,6}$=204	b_6=2035
Khulna (B7)	$C_{1,7}$=215	$C_{2,7}$=375	$C_{3,7}$=160	b_7=1159
Requirement	a_1=3980	a_2=1785	a_3=4856	

Table 5.1: Input data from the J & J Essential products (Pvt.) Ltd case study

According to the writer of the case study as a result of his optimisation the minimised transportation cost obtained was 861373 BDT [7]. When the proposed model of this research was applied on it the results obtained from MS Excel Solver and MATLAB respectively were as follows:

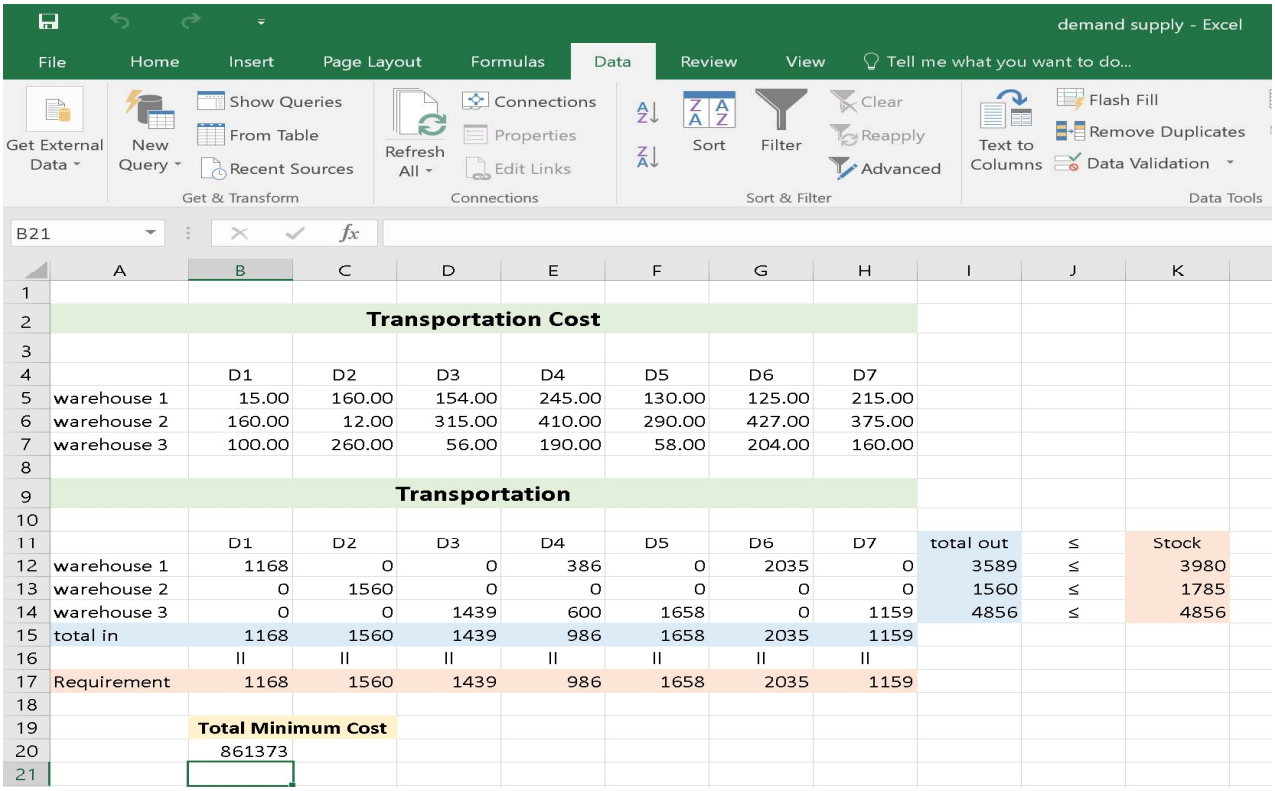


Figure 5.4: Optimized MS EXCEL SOLVER Results for the J & J Essential Products (Pvt.) Ltd case study

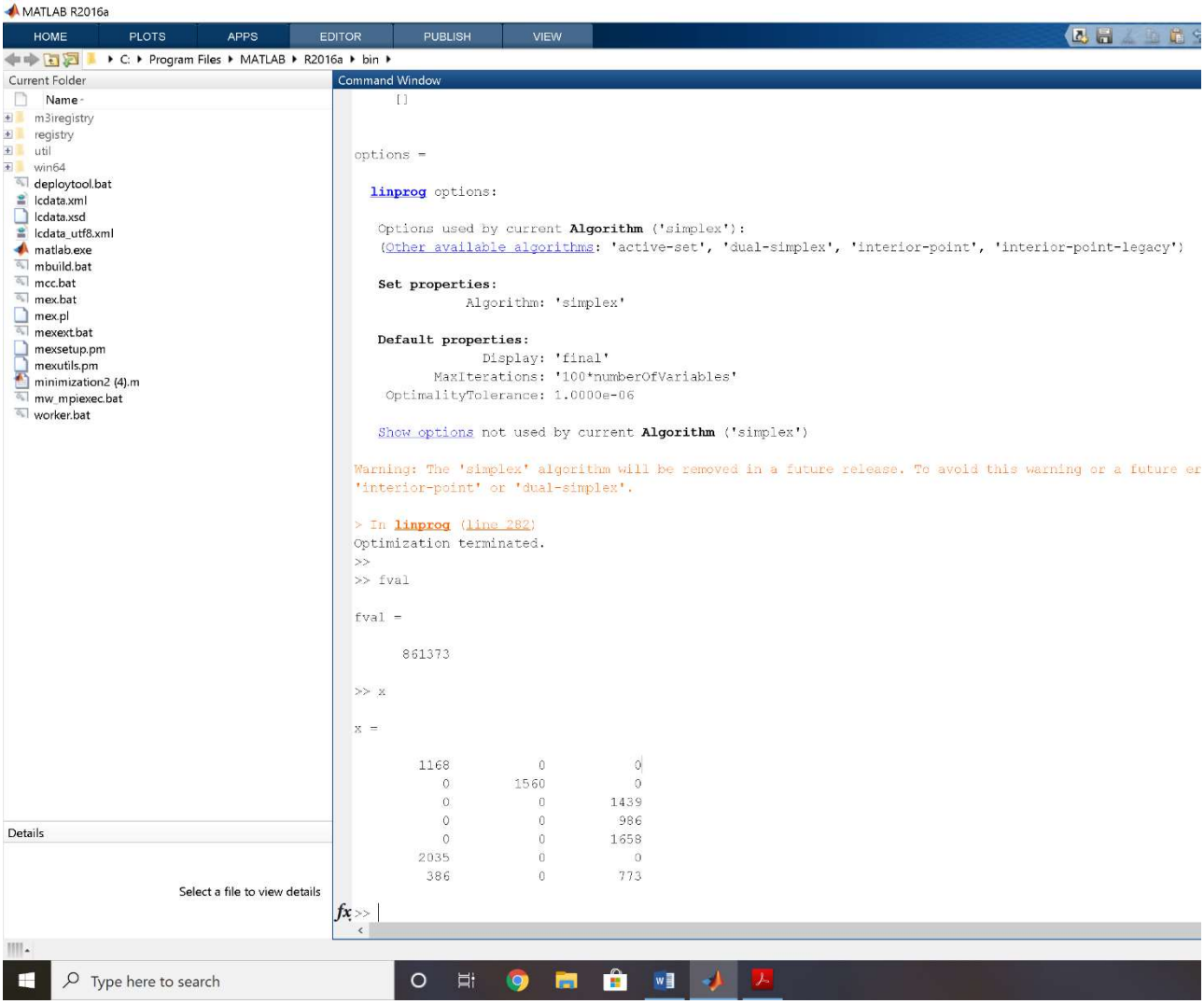


Figure 5.5: Optimized MATLAB Results for the J & J Essential Products (Pvt.) Ltd case study

As seen above the proposed model results matched with the J & J Essential Products (Pvt.) Ltd case study results. Therefore it can be applied to any similar case with sim ilar conditions.

CHAPTER 6. CONCLUSION

This research is based on developing a mathematical model based on integer linear programming. The model is used for the optimization of the transportation and damage cost for a third party logistics company. It revolves around transportation of multiple products from different warehouses to different destinations keeping in view the demand and supply constraints.

In this research a 3PL company with two warehouses in Rawat and Lawrencepur was considered as a case study. The company supplies multiple products for various companies all over the Pakistan. However, we considered two products cooking oil and banaspatee ghee as one unit only and their transportation to the northern Punjab and Khyber Pakhtunkhwa region was considered in this study.

The model developed was executed in MS EXCEL and MATLAB under the same conditions and then the solution was compared. the result showed a considerable saving in the transportation cost as compared to the reported cost by the company. I have used real time data for a month which was gathered from the corresponding organization. A total of 10.7 % of saving was observed (Rs. 901,698).

The following results were obtained after analysis for a month for two products only supplied from two warehouses by a 6 wheeler vehicle with truckload of 7300 kg:

- Total cost before optimization: Rs. 8,415,851
- After optimization for a combined total supply of 4925425 units:
- Combined total transportation cost is: Rs. 6,725,753 /-
- Combined total cost (with damage cost added) is: Rs. 7,514,153
- Difference in total cost =Rs. 8,415,851 - Rs. 7,514,153. = Rs. 901,698
- Percentage reduction in total cost = 10.7 %

More over other associated benefits were around 5 – 10 % which included:

- Reduced Maintenance Cost
- Less fuel consumption
- Increased life Expectance of vehicle
- Increased tyre life

CHAPTER 7. FUTURE RECOMMENDATION

A detailed study on the supply chain distribution networks, their working and flow of materials from source to destination and its optimization through mathematical modeling was carried out in this research using multiple softwares**.**

Although a lot of research is already done in this sector still there is a room of improvement in some areas. One of these can be supply chain network design optimization i.e. selecting best routes for transportation giving optimal solutions.

Other areas can be relocation of warehouses depending on the profitability a company can achieve with that.

A forward supply chain was considered for this research similarly reverse supply chain can be considered for optimization.

Same model can be further enhanced with more constraints in consideration.

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